AD-A069 908 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCH--ETC F/G 5/1

PROPOSED ALLOCATION TECHNIQUE FOR A TWO-CONTRACTOR PROCUREMENT.(U)

MAY 79 J L PELZER

UNCLASSIFIED AFIT/GSM/SM/77D-26 NL

1 OF 2

AD

A069908

1 LEVEL II

PROPOSED ALLOCATION TECHNIQUE
FOR A TWO-CONTRACTOR PROCUREMENT

THESIS

AFIT/GSM/SM/77D-26 Jay L. Pelzer
Captain USAF

(14) AFIT/GSM/SM/77D-26

GSM/SM/77D-26

(6) PROPOSED ALLOCATION TECHNIQUE
FOR A TWO-CONTRACTOR PROCUREMENT.

(9) Master's THESIS,

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

012 225

(12) 136 p.

by
(10) Jay L. Pelzer
Capt USAF
Graduate Systems Management

(11) 22 May ~~19~~79

012 225

xlt

## Preface

This thesis fulfills part of the requirement for a masters of science degree from the Air Force Institute of Technology, Wright-Patterson AFB, Ohio. There were several reasons for this research effort. Besides the fact that it was required, this research effort presented the writer with as opportunity to develop a solution to a problem on which little or no research had been done. The problem, identified initially by the A-10 SPO Director of Armaments, was determining the allocations to be awarded each contractor when two sources of supply are required for a procurement. Additional reasons for this effort included a desire to decrease Government procurement costs, as well as to foster competition to the greatest extent possible within the framework of this particular type of procurement.

As no research material was available on this particular type of procurement per se, the results of this effort are based on an extension of accepted economic theories and Government procurement practices, and on extensive testing with hypothetical data.

I would like to take this opportunity to express my most sincere appreciation to Dr. Norman K. Womer, my thesis advisor, for not giving up on me during the extended period required to complete this effort. I would also like to extend my appreciation to Dr. Womer for introducing me to this topic and for providing the majority of the classroom

# REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

| | |
|---|---|
| 1. REPORT NUMBER | GSM/SM/77D-26 |
| 2. GOVT ACCESSION NO. | |
| 3. RECIPIENT'S CATALOG NUMBER | |
| 4. TITLE (and Subtitle) | Proposed Allocation Technique for a Two-Contractor Procurement |
| 5. TYPE OF REPORT & PERIOD COVERED | MS Thesis |
| 6. PERFORMING ORG. REPORT NUMBER | |
| 7. AUTHOR(s) | Captain Jay L. Pelzer |
| 8. CONTRACT OR GRANT NUMBER(s) | |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | Air Force Institute of Technology/ENS<br>Wright-Patterson AFB OH 45433 |
| 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS | |
| 11. CONTROLLING OFFICE NAME AND ADDRESS | |
| 12. REPORT DATE | May 1979 |
| 13. NUMBER OF PAGES | 133 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) | |
| 15. SECURITY CLASS. (of this report) | UNCLASSIFIED |
| 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE | |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Approved for public release; distribution unlimited.

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

two-contractor procurement
multi-contractor procurement
allocation technique
competitive indices
minimum award requirement

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This thesis

This research effort proposes an allocation technique for use when two sources of supply are required for a large number of similar items over a period of years. Use of two contractors insures that a surge capacity will be available to meet sudden increases in demand. ~~However,~~ a problem arises in determining the portion of the total annual procurement to be allocated either contractor. This problem is even more acute when one ~~of the~~ contractors is able to offer prices which are significantly lower than those of his competitor. (over)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

(cont)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

**The proposed technique determines the allocations for both contractors based on relative competitive performance. For each competitor an annual competitive index is established using price bids and any other factor which the procuring agency deems appropriate. Overall competitive indices are then established for both contractors based on their annual indices for a three-year period. Annual allocations are determined using the ratio of the overall competitive indices.**

**The proposed technique is tested using hypothetical data. Included in the testing is a discussion of gaming techniques which might be employed by the competitors in order to gain unearned profits.**

A

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

instruction on which the logic of this effort is based. A special thankyou is given to Dr. Charles McNichols, thesis reader, for the patience he has shown in waiting for something to read.

Jay L. Pelzer

## Contents

## List of Figures

## List of Tables

## Abstract

This research effort proposes an allocation technique for use when two sources of supply are required for a large number of similar items over a period of years. This procurement scenario was identified by the A-10 SPO in their procurement of 30mm ammunition. Use of two contractors insures that a surge capability will be available to meet sudden increases in demand. However, a problem arises in determining the portion of the total annual procurement to be allocated either contractor. This problem is even more acute when one of the contractors is able to offer prices which are significantly lower than those of his competitor.

The proposed technique determines the allocations for both contractors based on relative competitive performance. For each competitor an annual competitive index is established using price bids and any other factor which the procuring agency deems appropriate. Overall competitive indices are then established for both contractors based on their annual indices for a three-year period. Annual allocations are determined using the ratio of the overall competitive indices.

The proposed technique is tested using hypothetical data. Included in the testing is a discussion of gaming techniques which might be employed by the competitors in order to gain unearned profits.

# I. INTRODUCTION

## Background

The subject matter for this research effort stems from a problem which was encountered by the A-10 System Program Office, Director of Armaments Branch, during the procurement of GAU-8 30mm ammunition. The following information is an overview of the more pertinent factors of this problem.

The GAU-8 weapon system, produced by General Electric, is the primary weapon system of the A-10 close air support aircraft. This system is built around a seven-barrel Gatling-type gun which uses three kinds of 30mm ammunition: HEI (High Explosive Incendiary), API (Armor Piercing Incendiary), and TP (Target Practice). This ammunition can be fired at a selected rate of either 2000 or 4000 rounds per minute. In addition to the three kinds of ammunition fired by the gun, dummy rounds are also being procured for use in weapon system checkout and maintenance.

The Armaments Branch of the A-10 SPO is responsible for the procurement of all GAU-8 ammunition through FY 1983. The Army Armament Command (ARMCOM) will then assume this responsibility.

Although there is a planned schedule for the number of rounds to be procured each year through FY 1984, the number of rounds which could be required in any given year is subject

to various factors beyond the control of the procuring agency. A common factor which affects the level of any Department of Defense program is the amount of funding made available each year for that program. A shifting of emphasis among Air Force programs could bring about a substantial increase, or decrease, in the number of rounds of GAU-8 ammunition to be procured.

The most drastic change in procurement requirements would be brought about by Air Force involvement in an armed conflict requiring extensive use of the A-10 aircraft. In order to reduce the possibility of having insufficient ammunition available when needed, a mobilization base must be maintained with adequate capacity to meet the suddenly increased demand caused by an armed conflict.

The Aerojet Ordnance and Manufacturing Company and the Honeywell Government and Aeronautical Products Division are both under contract to produce GAU-8 30mm ammunition. These contractors provide the needed mobilization base and satisfy the Defense System Acquisition Review Council (DSARC) established guideline for a competitive procurement. The problem encountered by the Director of Armaments was that of determining what portion of the annual ammunition procurement was to be awarded, or allocated, to each of the contractors.

The normal solution in a competitive procurement situation is to purchase the contracted items from the producer who will supply them at the least cost to the Government. In this particular situation, awarding a 100% allocation to

the lowest bidder is not considered a feasible solution. First of all, awarding 100% of the contract to either contractor would weaken the desired mobilization base, unless of course the Government were willing to provide substantial additional funding to maintain the other contractor as a part of the mobilization base. The second constraint which a 100% allocation would violate is that of maintaining the required competitive sources of procurement. To award 100% of the production requirement for any given year to either contractor would leave little chance that the other contractor would be in a competitive pricing position for the procurement of the following year. Again, that is unless the Government were willing to provide substantial additional funding for the other contractor.

An award of 100% of the production requirement to either contractor is too high. Therefore, a significant part of the two-contractor allocation problem is the determination of the maximum portion to be allocated to either contractor. This part of the problem was solved by the A-10 SPO determination of a Minimum Sustaining Rate (MSR) for the contractor awarded the smaller allocation of the annual procurement. During the first years of the GAU-8 ammunition procurement it was estimated that each contractor must receive at least 20% of the total annual procurement in order to satisfy the MSR requirement. This MSR would have left the Director of Armaments 60% (100% - (2)20%) to apportion between the two contractors.

The Armaments Branch also estimated, however, that the minimum economically feasible allocation for either contractor would be approximately 40% of the annual procurement. A contractor receiving less than this amount would have difficulty being in a competitive bidding position for the following year's procurement. This factor meant that only 20% (100% - (2)40%) was actually subject to competitive pricing of the contractors.

Due to the requirements for maintaining both a sufficient mobilization base and a competitive procurement environment, a straightforward minimum cost procurement has been infeasible. What has been needed is a technique which would allow the Director of Armaments to apportion the annual GAU-8 30mm ammunition procurements between Aerojet and Honeywell in such a way as to insure that each contractor would be awarded at least an economically feasible rate and, at the same time, encourage active price competition.

General Electric originally selected Aerojet as the subcontractor for the development of the GAU-8 ammunition. As this was prior to the requirement that two contractos be utilized. Aerojet had a full year advantage in production experience with this type of ammunition before Honeywell was selected as the second contractor. In view of this experience advantage, Aerojet has had a substantial pricing advantage over Honeywell when bidding for the annual procurement allocations. This fact, coupled with the requirement that

Table I

GAU-8 Ammunition Procurement Schedule

| | FY75 | FY76 | FY77 | FY78 | FY79 | FY80 | FY81 | FY82 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| TP | 200* | 400 | 1080 | 2244 | 2002 | 2064 | 2024 | 2024 | 12038 |
| HEI | 175 | 326 | 1376 | 1755 | 5620 | 5620 | | | 14872 |
| API | 83 | 650 | 1710 | 3250 | 3250 | 3250 | 3286 | | 15479 |
| | 458 | 1376 | 4166 | 7249 | 10872 | 10934 | 5310 | 2024 | 42389 |

*number of rounds in thousands

each contractor be awarded at least the economically feasible rate, rendered the annual minimum unit list price bids, in themselves, inadequate as the basis for active competition.

The normal behavior of firms engaged in an oligopoly, which in this case is the more restrictive duopoly, does not directly apply to this procurement problem. The GAU-8 ammunition procurement involves the notable oligopoly characteristics of "a small number of firms and a great deal of interdependence, actual and perceived, among them"(Ref 9:348). However, the total demand for GAU-8 ammunition has not been a function of the unit list price bids (market price) of the contractors. Instead, the total demand has been fixed for each year in accordance with a planned procurement schedule. Table I shows the planned actual procurement schedule as of March 1977. It is because of the minimum award being fixed at the minimum economically feasible rate and the total

demand being fixed in accordance with the planned schedule that normally accepted oligopolistic theories have not been able to provide a solution to this problem.

It is only recently that the unit line price bids of Aerojet and Honeywell have reached comparable levels. This is due partly to the fact that Honeywell has had an opportunity to make up the experience disadvantage is suffered in previous years. And, because the unit line price bids have been drawing closer with each year, the Director of Armaments was able to test a new allocation technique during a recent supplemental procurement. Even though the new allocation technique is suspected of having had a significant effect on the bidding by the contractors, the Director of Armaments is still not satisfied with the level of competition because of what are considered to be unacceptably high profit levels for both contractors.

## Objectives of the Research

The primary objective of this report is to develop a technique for the apportionment of procurement requirements under circumstances similar to those described in the A-10 Director of Armaments problem of the previous section. The technique which will be developed is intended for the use of future programs which may encounter similar circumstances. However, in view of the numerous similarities, this report may also be used by the A-10 SPO Director of Armaments

Branch to evaluate the allocation method which is currently in use.

The proposed technique must support the directive of the Defense System Acquisition Review Council that two contractors be employed for the procurement in order to help reduce program costs by creating a competitive procurement environment (Ref 4:3). The preferred technique, therefore, is one which will result in an apportionment based on some factor, or factors, which will encourage the greatest amount of price competition between the two contractors. Since the contracts are to be awarded over a period of more than one year, some function of each contractor's unit list price bids with respect to time should provide an acceptable basis for encouraging competition between the contractors.

The emphasis of this report is on the development of an equation for use in determining the allocation to be awarded each contractor in any given year. The allocation for each contractor will be expressed as a percentage of the total procurement requirement for that year. The use of percentages, rather than absolute numbers of units to be procured, will allow the same technique equation to be used regardless of the magnitude of procurement requirements from one year to the next. The resulting equation should enable the procuring SPO Director to employ as many factors as desired for the allocation competition. The allocation equation should further allow for the weighting of each factor according to the degree of importance assigned to it in relation to the importance

of the unit line price. Besides the ability to vary the number of factors used in this technique, the SPO Director should also be able to vary the responsiveness of the contractor allocations as a function of the competitive factors. The reason for this last provision is to counteract the possible advantage one contractor may gain over the other if only one contractor is used during the developmental stage of the program.

Scope, Assumptions, and Limitations

The scope of this research effort has been limited to the apportionment of the total annual procurement requirements less the portions awarded either contractor to fulfill any minimum award requirements. Minimum award requirements may include either MSR or *minimum economically feasible rate*, or both. The minimum award requirements are treated as fixed percentages of the annual procurement and are not subject to the competitive performance of either contractor. Furthermore, the purpose of this report is not to evaluate the DSARC decision which requires the use of more than one contractor, but rather to find a means of allocation which will support the purpose of this decision.

This study was based on the following assumptions and limitations:

1. The procurement involves a large number of individual items. This assumption is necessary if the procurement requirements are to be allocated on a percentage basis. The

number of units involved should be at least 100 X $10^n$, where "n" is the number of significant digits following the decimal point in the allocation percentages. For example, in order to make the allocations to the nearest .01 percent, at least 100 X $10^2$, or 10,000 units should be involved.

2. It is assumed that both contractors will behave in a competitive manner because they will prefer more to less in the apportionment of the annual procurement requirements.

a) Neither company will be satisfied with a minimum award if there is a reasonable expectation of increasing profits by increasing their respective allocation. In any given year, the total profit received by either contractor should vary directly with the allocation received by that contractor.

b) Both companies are assumed to be capable of competing with each other at a level which would enable them to receive more than the minimum award in any given year. For either company the minimum award would be the least desirable allocation.

3. There is a limitation as to how well the competitive behavior of either contractor can be predicted. Regardless of the amount of cost and profit data which is obtained, it is impossible to determine the full extent to which either contractor will be either willing or able to compete.

4. This report assumes that only two contractors will be used for the procurement. The use of two contractors will

provide the desired competitive environment. Because of the minimum award requirements for each contractor, the addition of a third contractor would lower the portion of the total annual procurement which is subject to the competition. A decrease in the portion subject to competition would have a negative effect on the motivation for the contractors to compete.

## Methodology

The first task in doing research for this report was to become familiar with the GAU-8 30mm ammunition procurement program. This was accomplished through discussion with personnel from the A-10 SPO Director of Armaments Branch and a review of government cost studies. Theses by Captains Richard Wall (GSM/SM/75S-10) and Robert Nadeau (GSM/SM/76S-19) provided additional background information. Historical prices for GAU-8 ammunition contracts of prior years were made available by the A-10 SPO Director of Armaments Branch.

These same sources were also used to select items, other than unit line price bids, which could be used as possible additional factors for the competition. A literature search was also made for additional factors. A method of weighting the additional factors was then developed. This method was tested to insure that the impact of the additional factors on the allocations did in fact reflect the relative weights assigned to these factors.

A survey was made of literature pertaining to the oligopolistic and duopolistic behavior of competitive firms. The purpose of this survey was to determine whether or not the current theories regarding such behavior could be used either to encourage competition or to predict the competitive performance of the two competing contractors.

The search for an acceptable allocation equation began with the simplifying assumption that if all things were equal for both contractors, then each would receive an allocation of 50% of the total annual procurement. "All things", in this case, is used to refer to all those factors which affect production, costs, or the unit line price bids of the contractors. Included in these factors would be the types of equipment used, the skill levels of the direct labor force, the talent and innovation of the management personnel, the costs of materials procured from subcontractors, the profit levels included in the unit line price bids of both contractors. With all things being equal, and held at a constant level, the unit line prices (in constant dollars) bid by both contractors would be expected to decrease each year by the amount saved because of the effect of the learning factor on the direct labor input to production. In this assumed situation, each year the ratio of the unit line price bid of one contractor to that of the other would be one-to-one (1:1).

The simplifying assumption of all things being equal is an extreme assumption which obviously does not correspond to

the actual situation for any two contractors. The use of this assumption was for the sole purpose of establishing a starting point at which both contractors would be awarded equal allocations. After establishing this starting point, the equality constraint on each factor could be relaxed to determine what effect it would have on the competition. Relaxation of the constraints also means that the ratio of one contractor's unit line price bids to the bids of the other contract would no longer have to be 1:1.

The selection of some function of the individual contractor's annual unit line price bids with respect to time as the primary basis for the allocation competition was made because it could be used to compensate for any possible learning factor advantage gained by one contractor having been selected prior to the competing contractor.

For the simulation of how the proposed allocation technique would be applied, two hypothetical contractors, Company A and Company B, and hypothetical prices are used. Testing of the proposed technique is accomplished by attempting to "game" the bidding on the part of the competing contractors.

## Organization

This thesis is organized as follows: A discussion of factors, other than unit line bid price, which may be used as competitive factors is found in Chapter II. Chapter III discusses the development of, and the reasoning behind, the

proposed allocation technique. In Chapter IV the proposed technique is demonstrated and tested. The testing section also includes a discussion of attempted competitor gaming. Conclusions and recommendations are given in Chapter V.

# II. APPLICATION OF ADDITIONAL COMPETITIVE FACTORS

## Introduction

The purpose of a competitive procurement is to reduce the overall program costs to the Government. As a result, the prices bid by the competing contractors are normally used as the sole factor on which to base the competition. And, after the competition, 100% of the procurement is awarded to the one contractor who submitted the lowest bid. With an extended procurement in which more than one contractor is retained, a number of factors may be used together as bases for the competition.

The possible number of factors which may be used is limited only by the number of measurable differences which can be found between the competitors. In order to insure that the emphasis is placed on reducing the overall program costs, the prices bid by the competitors must be maintained as the most significant factor. This can be accomplished by weighting any additional factor on the basis of its importance relative to the unit line price bids of the competitors.

The Weighted Guidelines method of the Armed Services Procurement Regulation (ASPR) lists several factors which must be considered when determining profit in the absence of competition. Because it is used to "assure that appropriate considerations are given to all relevant factors" (Ref 2:49),

the Weighted Guidelines method may be of assistance in suggesting some additional factors on which to base the two-contractor competition. Those factors which are cost elements of the unit line price bids should not be included as additional factors in the competition. As a part of the prices bid by the competitors, these factors are already included in the competition.

This chapter discusses items which may be used as additional factors in the competition. It also explains the method of weighting which is used in the proposed allocation technique.

## Additional Factors

The factors discussed in this section have been selected as representative of three areas which may be of concern to the procuring agency: cost risk; contractor performance; and characteristics of the procured items. The factors which are actually used for the competition would be left to the discretion of the procuring agency.

Degree of Contractor Cost Risk. "The Government, like any other buyer, wants its suppliers to assume as much of the cost risk for the procurement as is fair. This is why the Government prefers the firm-fixed price type of contract" (Ref 2:33). With a firm-fixed price contract, the cost risk shareline is 0/100 percent. This means that, with a cost overrun, the Government has zero risk, and the contractor would be required to cover 100% of the additional cost.

On the other hand, a contract which uses an incentive type arrangement may have a share line of either 20/80, or 50/50, or any combination adding up to 100 percent. With any of these share lines, the Government would be required to pay a varying share of any cost overrun. Therefore, the procuring agency would prefer that the contractor assume as much of the risk as possible.

There are two ways in which the procuring agency could benefit by the use of contractor risk as a competitive factor. The first way is that both competitors are given an incentive to accept a larger share of the risk. Should this incentive prove to be insufficient, the procuring agency still has a second benefit in that the competitor assuming the greater risk would receive an allocation which is greater than the one he would receive were this factor not included. In either case, the overall risk to the procuring agency is reduced.

Contractor Performance. "A contractor should be rewarded on the basis of demonstrated past performance...timely deliveries, quality, value engineering accomplishments, and similar performance evaluation criteria should be considered" (Ref 2:53). Because the competitive procurement under consideration is assumed to extend over a period of years, this factor may be used either to reward or to penalize a contractor based on his year-to-year performance for this procurement. The benefit derived from inclusion of this factor

is that it provides an incentive for the competitors to improve their performance in those areas which are not directly reflected in their unit line price bids. Improvements in such areas as timeliness of deliveries and cost accounting procedures may provide substantial benefit for the procuring agency.

Procured Item Performance. The performance and reliability of the procured item itself may, or may not, be included as means of judging contractor performance. By treating them as a separate factor, emphasis can be placed on improvement of the procured item. Performance characteristics, such as variations in speed, range, or reliability, are more easily and accurately measured than are the subjective contractor performance characteristics, such as management, efficiency, or special *achievement*. The use of objectively measured factors may prove to be more effective in that it provides the competitors with more certainty in the analysis of their own performance. With subjectively measured factors, decisions as to tradeoffs between price and performance could require a great deal of conjecture, on the part of the competitors, as to the evaluations of the procuring agency.

## Weighting the Additional Factors

The weight assigned to each additional competitive factor is a measure of the importance of that factor relative

to the importance of the unit line price. This weight is expressed as the ratio of a one percent increase in the value of the additional factor to the value of a one percent decrease in the unit line price. The change in value of an additional competitive factor is measured as the percent change from the standard established for that factor. The percent change in unit line price is based on the bid price of the current year's procurement. It is therefore recommended that the standard for each competitive factor be established at the average level of the competitors' expected performance. By establishing the standard at this level, tradeoffs between decreased price and increased performance can be approximated by the comparison of the changes from the present levels of either competitor.

The following equation is used in applying the additional factors to the competitive procurement:

$$F_x = \left[ 1 + \left( w_x \left( 1.00 - \frac{r_x}{s_x} \right) \right) \right] \tag{1}$$

where $F_x$ is an index value for additional factor "x", $\underline{w}$ is the weight assigned to this factor, $\underline{s}$ is the standard value established for this factor, and $\underline{r}$ is the performance rating received by the competitor for this factor. If product reliability were included as an additional factor, and assigned a standard value of .98 with a weight of .25, then for a competitor with a product which performs properly 94 times out of 100, the index value would be computed as

follows:

$$F = \left[ 1 + ( .25 ( 1.00 - \frac{.94}{.98} ) ) \right]$$

$$= \left[ 1 + ( .25 ( .0408 ) ) \right]$$

$$= \left[ 1 + ( .0102 ) \right]$$

$$= 1.0102$$

This index value is then used in determining an annual competitive index for each of the competing contractors. The annual competitive index is determined by multiplying the unit line price bid of either competitor by his index values for the competitive factors. The equation used to compute the annual competitive index for either competitor is:

$$I_c = (p_c)(F_1)(F_2)(F_3)\ldots(F_n) \qquad (2)$$

where $I_c$ is the annual index for competitor "c", $\underline{P}$ is the number of dollars in the unit line price bid of the competitor, and $\underline{n}$ is the number of additional competitive factors used in the competition. If $\underline{n}$ equals zero, then $I_c$ equals $P_c$, and the competition is based solely on the unit line price bids of the competitors.

Using reliability, from the previous example, as the only additional factor, with a unit line price bid of \$100, the competitor's annual index would be computed as follows:

After computing an annual competitive index for the other competitor, the two indices are then used in place of

Table II

Other Competitive Factors

| Contractor | Procured Item |
| --- | --- |
| Profit rate | Weight |
| Dollar value of Government furnished equipment | Maximum temperature |
| Percent of materials which are subcontracted | Displacement |
| Production rate | Mean time to failure |
| Percent of employees from minority groups | Useful life |
| | Noise level |

$$I = (100)(1.0102)$$
$$= 101.02$$

the unit line price bids as the basis on which to award the annual procurement allocations.

Some other items which could be included as additional competitive factors are listed in Table II. However, this list is not intended to be all-inclusive. It is only to show the wide range from which additional competitive factors may be selected.

# III. DEVELOPMENT OF THE PROPOSED ALLOCATION TECHNIQUE

## Introduction

This chapter is a step-by-step description of the procedures followed in the development of the proposed allocation technique. Explanations of the reasoning used for either testing or modifying the proposed technique are included with this description. The development process begins with the assumption that, if all factors were equal for both competitors, both would perform at equal levels, and both would receive equal awards. In this case, equal awards would be allocations of 50% of the total annual procurement for which the contractors are competing. With the previous assumption as the starting point, the constraint that all factors be equal is then released one factor at a time. As each factor is allowed to become unequal for the competitors, the effects of that factor on the competition are examined.

Consideration is given to the possibility that one contractor (Company A) might have been under contract prior to the time that a competitor (Company B) is included for the procurement competition. Because a learning, or experience, factor in production allows successive units of an item to be produced with decreasing amounts of direct labor per unit, Company A would be expected to have a cost advantage over

Company B from the outset of the competition. The basic idea behind the proposed allocation technique comes as a result of trying to compensate Company B for this disadvantage, while at the same time retaining the unit line price bids of the competitors as the main factor in the procurement competition.

The reduction of overall program cost to the government is the primary purpose behind the use of a competitive procurement. In order to give the greatest support to this purpose, the proposed allocation technique employs the unit line price bids of the competitors as the primary factor on which to base the procurement competition. However, the unit line price bids are not, by themselves, the sole factor on which the competition may be based.

The development of an allocation technique which can be stated in terms of an equation, or a combination of equations, makes possible the use of a multiplicity of factors as bases for the competition. The use of an equation also allows for the weighting of the selected competitive factors so as to reflect the relative importance of each with respect to the importance assigned to the unit line price bids. This ability to both select and weight additional factors is incorporated in order to increase flexibility in the application of the proposed technique by the procuring agency.

As the development of the proposed technique progresses, hypothetical data is used to insure that the intended results are obtained. Attempts, on the part of the competitors, to "game" the proposed technique will also be tested.

Assumption of Complete Equality

The assumption made here is that Company A and Company B are equal in all respects. This equality is assumed to be so complete that the two companies would be almost indistinguishable were it not for the difference in company names. Under these assumed conditions, the two companies would have exactly the same types and amounts of equipment, equally skilled labor forces, equally talented and innovative managerial personnel, identical suppliers and subcontractors, identical methods of production, identical salary and wage rates, and would charge equal rates of profit on their profits. Implicit in the assumption that all of these factors of production, cost, and profit are equal, is the assumption that the product and the unit line price bids of both companies would also be equal.

Admittedly, such complete equality of both input and output for both companies is an extremely unrealistic assumption. But, the assumption does serve a useful purpose in that it establishes a starting point with only one logical allocation breakdown. Regardless of the allocation technique used, if both competitors are equal in all respects, and if the allocations awarded are to reflect relative competitive performance, then both would be awarded equal allocations of 50%.

In order to progress from this starting point, the assumed equality constraint must be relaxed due to the fact that "there are...inevitable differences in operating characteristics between any two firms, stemming from the equipment,

methods, product design, plant organization, etc." (Ref 7:531). By individually releasing the various cost elements from the equality constraints, the effect that each cost element has on the unit line price bids may be examined. Only some of the major factors which influence the unit line price bids will be discussed. However, the following discussion is considered sufficient for the purpose of demonstrating that the competitive advantage for any factor goes to the competitor for whom that factor would result in the lower unit line price bid.

The first cost element examined, after release of the equality constraint, it the equipment used for the manufacture of the procured items. Various combinations of equipment and labor can be used to produce the same product. A contractor may decide to use either a highly automated production system, which requires a relatively small amount of direct labor, or a more labor intensive system requiring less complex equipment, or any combination in between.

Several of the possible combinations may be equally efficient in a technological sense, but only one combination is the most economically efficient. (Ref 6:448) Depending on the basis used to determine the economic efficiency of the system, the contractor may have two alternatives to choose from. The contractor may select either the mix of capital and labor which is most economically efficient for the production of the procurement items only, or he may select the

mix which is most economically efficient for the entire, procurement and nonprocurement, production of the firm. In either case, the competitor who selects the mixture with the lower cost of producing the procurement items will have the competitive advantage for this cost factor.

The labor force employed by either contractor will also influence the competition. Since wages normally vary with the skill levels and experience of the workers, the contractor who is better at matching the workers with the tasks required will gain a competitive advantage. It is the responsibility of the contractor to insure that he neither pays excessively high wages for workers with unnecessarily high skill levels, nor pays for an unnecessarily high number of less skilled workers.

The management personnel employed by either contractor also influence the costs used in determination of the unit line price bids. The greater the talent, or managerial skill level, of these personnel, the better chance a contractor has of performing in the most efficient manner. Additionally, the more innovative these personnel are, the greater the possibility of reducing costs through improved methods. A detailed analysis of all the possible contributions which management may make is not necessary. The important point to be realized is that the competitor with the more effective management will have a competitive advantage in this area.

Differences in the costs of materials, services, or other items received from suppliers and subcontractors will

also have a significant influence on the unit line price bids of the competing firms. For this cost element the competitive advantage in any given year would belong to the contractor with the lower-priced outside sources during that year. The overall advantage in this cost area, when viewed over the entire period of the procurement competition, is not dependent upon having the lower-priced sources in any particular year. In order to gain the overall advantage, it is incumbent upon the competitors to find those outside sources which will offer the lowest prices over the entire period.

The only factor of unit line price over which the competing contractors would have complete control is the profit rate used to determine the bid price. The profit rate itself, however, does not give either competitor an advantage. The advantage would go to the competitor with the lower profit, which is a function of both cost and profit rate. Therefore, either contractor should be able to improve his relative competitive position by decreasing the profit rate charged.

The effects of the learning factor on both competitors must also be considered. There is the possibility that one contractor may have a competitive advantage gained from production experience prior to the time the procurement is subjected to competitive allocations. This situation would normally be expected as a result of one of the competitors having been under contract during the development of the item

being procured. The following section of this report discusses both the effects of the learning factor and the method used to compensate for these effects in the proposed procurement allocation technique.

## Effects of the Learning Factor on Competition

"The cost effects of changing manual dexterity, the application of certain management innovations, and the interaction between manual dexterity and various management innovations are measured and predicted by the learning curve" (Ref 3:176). This "learning curve, in its basic form, is simply a line displaying the relationship between unit production time and the number of consecutive units of production" (Ref 7:526).

The theory of the learning curve is that as output is doubled, there is a constant "percent reduction in direct production man-hours per unit between doubled units" (Ref 7: 526). For example, with a learning factor of 80%, or .80, if it requires 100 man-hours to produce the first unit, then the second unit would require 80 hours (100 X .80). The fourth unit, which is double the output as the second unit, would require only 64 hours (80 hours X .80). "Another way to express this is that the cost of direct labor hours of the doubled quantity is 80 percent of its initial value," or "for each 100 percent increase (or doubling) in the quantity of units produced, there would be a 20 percent decrease in man-hours for that quantity" (Ref 3:177).

Table III

Data for a Learning Factor of .80

| Sequential Production Unit | Man-hours Required for Indicated Prod. Unit | Difference in Man-hrs per Unit at Doubled Quantities | Percent Difference at Doubled Quantities |
|---|---|---|---|
| 1 | 100.000 | | |
| 2 | 80.000 | 20.000 | 20% |
| 3 | 70.208 | | |
| 4 | 64.000 | 16.000 | 20% |
| 5 | 59.580 | | |
| 6 | 56.166 | | |
| 7 | 53.431 | | |
| 8 | 51.200 | 12.800 | 20% |
| 9 | 49.279 | | |
| 10 | 47.664 | | |
| 11 | 46.215 | | |
| 12 | 44.933 | | |
| 13 | 43.851 | | |
| 14 | 42.774 | | |
| 15 | 41.825 | | |
| 16 | 40.960 | 10.240 | 20% |
| 17 | 40.171 | | |
| 18 | 39.431 | | |
| 19 | 38.765 | | |
| 20 | 38.112 | | |
| - | | | |
| 32 | 32.768 | 8.192 | 20% |

The data for a learning factor of .80 is given in Table III. Examination of this data demonstrates a major disadvantage which may be faced by Company B if it is employed as a

competitive contractor subsequent to Company A having been employed.

In order to demonstrate the disadvantage to Company B, the following conditions will be assumed. Each production unit will represent 1,000 similar items. The procurement allocations will be awarded such that the competitor with the higher unit line price bid will receive an allocation of 40% of the procurement requirement. This 40% allocation represents a minimum award requirement for either contractor. The remaining 60% of the procurement will be awarded to the competitor having the lower unit line price bid.

It is arbitrarily assumed that Company A has produced seven production units of this particular procurement item prior to Company B being included for procurement competition. If, in the first year of the procurement competition, both companies are asked to submit bids for a procurement of five production units (5,000 items), Company A will make its bid based on the man-hour requirements of sequential production units 8 through 12. The bid by Company B will be based on the man-hour requirements of sequential production units 1 through 5. By applying the earlier assumption of all things being equal, but now with the exception that Company A has an experience advantage in the production of this item, the effects of the learning factor on the unit line price bids of both competitors can be examined.

For the first year of the competitive procurement, with a common wage rate of $10 per man-hour and a common profit rate of 10%, for each of the competitors the man-hour cost, including profit, used to determine their unit line price bids would be:

Year 1

| Company A | | | Company B | | |
|---|---|---|---|---|---|
| Unit No. | Man-hours Required | Cost | Unit No. | Man-hours Required | Cost |
| 8 | 51.200 | $512.00 | 1 | 100.000 | $1000.00 |
| 9 | 49.279 | 492.79 | 2 | 80.000 | 800.00 |
| 10 | 47.664 | 476.64 | 3 | 70.208 | 702.80 |
| 11 | 46.215 | 462.15 | 4 | 64.000 | 640.00 |
| 12 | 44.933 | 449.33 | 5 | 59.580 | 595.80 |
| Labor cost | | $2392.91 | Labor cost | | $3737.88 |
| Profit on labor | | 239.29 | Profit on labor | | 373.79 |
| Total | | $2632.20 | Total | | $4111.67 |

The bid submitted by Company B would include $1,479.47 more for direct labor man-hours required. Because all other factors are assumed to be equal, the difference in bid prices would equal the difference due to direct labor man-hours required.

Therefore Company A would be awarded the 60% allocation of three production units. Company B would be awarded 40%, or two production units. With these allocations for the first year, in the second year of the competition Company A would bid based on production units 11 through 15, and Company B based on production units 3 through 7. The direct

labor costs, including profit, which would be reflected in the unit line price bids for the second year would be:

Year 2

| Company A | | | Company B | | |
|---|---|---|---|---|---|
| Unit No. | Man-hours Required | Cost | Unit No. | Man-hours Required | Cost |
| 11 | 46.215 | $462.15 | 3 | 70.208 | $702.08 |
| 12 | 44.933 | 449.33 | 4 | 64.000 | 640.00 |
| 13 | 43.851 | 438.51 | 5 | 59.580 | 595.80 |
| 14 | 42.774 | 427.74 | 6 | 56.166 | 561.66 |
| 15 | 41.825 | 418.25 | 7 | 53.431 | 534.31 |
| Labor cost | | $2195.98 | Labor cost | | $3033.85 |
| Profit on labor | | 219.60 | Profit on labor | | 303.39 |
| Total | | $2415.58 | Total | | $3337.24 |

The bid submitted by Company B would be $921.66 greater than that submitted by Company A.

Company A and Company B would again be awarded allocations of 60% and 40% respectively. In the third year of the competition Company A would then make its bid based on the man-hour requirements of production units 14 through 18, and Company B based on the requirements of production units 5 through 9. The costs reflected in the bids for the third year would then be:

Year 3

| Unit No. | Man-hours Required | Cost | Unit No. | Man-hours Required | Cost |
|---|---|---|---|---|---|
| 14 | 42.774 | $427.74 | 5 | 59.580 | $595.80 |
| 15 | 41.825 | 418.25 | 6 | 56.166 | 561.66 |
| 16 | 40.960 | 409.60 | 7 | 53.431 | 534.31 |
| 17 | 40.171 | 401.71 | 8 | 51.200 | 512.00 |
| 18 | 39.431 | 394.31 | 9 | 49.279 | 492.79 |
| Labor cost | | $2051.61 | Labor cost | | $2696.56 |
| Profit on labor | | 205.16 | Profit on labor | | 269.66 |
| Total | | $2256.77 | Total | | $2966.22 |

The bid submitted by Company B would then be $709.45 greater than that submitted by Company A. Again, Company A and Company B would be awarded allocations of 60% and 40% respectively.

Table IV lists, for the first eight years of the competition, the results which would be expected under the assumed conditions used for this example. The results are listed for both a 40% minimum award requirement and a 20% minimum award requirement. Due to the higher unit line price bids, Company B would be awarded the minimum award requirement allocation in all eight years.

The behavior of the expected direct labor cost, including profit, for both competitors is depicted in Fig. 3.1. The behavior of these costs is demonstrated by graphing the annual costs as the percentage that each is of its preceding year cost. Separate curves are graphed for each of the competitors

Table IV

Expected Direct Labor Costs*

| Year | With 40% Minimum Award Requirement | | With 20% Minimum Award Requirement | |
|---|---|---|---|---|
| | Company A | Company B | Company A | Company B |
| 1 | $2,632** | $4,112 | $2,632 | $4,112 |
| 2 | 2,416 | 3,337 | 2,358 | 3,629 |
| 3 | 2,257 | 2,966 | 2,172 | 3,339 |
| 4 | 2,134 | 2,726 | 2,034 | 3,128 |
| 5 | 2,034 | 2,551 | 1,928 | 2,966 |
| 6 | 1,952 | 2,416 | 1,837 | 2,835 |
| 7 | 1,882 | 2,305 | 1,765 | 2,726 |
| 8 | 1,821 | 2,213 | 1,706 | 2,632 |

* the expected costs listed include 10% profit

** amounts are rounded to the nearest whole dollar

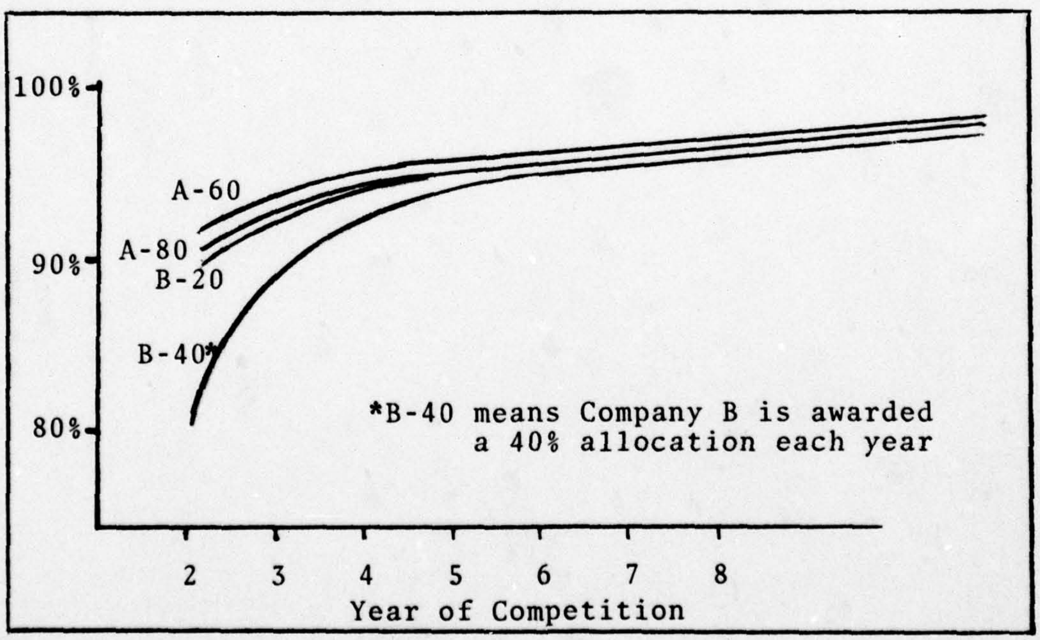



Figure 3.1. Expected Direct Labor Cost as a Percent of the Previous Year Cost

using both 40% and 20% minimum award requirements for the annual allocations. This figure is used to demonstrate the fact that the direct labor man-hour requirement costs decrease at different decreasing rates. The rate at which the costs decrease is dependent upon the annual allocations awarded each competitor.

The percentages depicted in Fig. 3.1 are listed as decimals in Table V. Table V also lists the annual ratios of the expected costs for Company B to the expected costs for Company A. These ratios are then graphed in Fig. 3.2.

Fig. 3.2 illustrates changes in the ratio of the costs for Company B to the costs for Company A. These ratios are depicted for both the 40% and the 20% minimum award requirements. This figure shows that, over time, the ratio of the costs for Company B to those for Company A becomes an almost constant value. With the 40% minimum award requirement, the cost ratio becomes nearly constant when the costs for Company B are approximately 1.17 times the costs for Company A. Using a 20% minimum award requirement, the ratio becomes nearly constant at approximately 1.54 times the costs for Company A.

A comparison of Fig. 3.1 with Fig. 3.2 shows that as the percentage change in annual cost for both competitors becomes equal, under either minimum award requirement allocation, the ratio of the costs for one contractor to the costs for the other contractor approaches a nearly constant value. Therefore, even if the levels of production experienced at the

Table V

Ratios of Expected Direct Labor Costs

| Year | Allocations Based on a 40% Minimum Award Requirement | | |
|---|---|---|---|
| | Bid Year Expected Cost / Prior Year Expected Cost | | Co. B Expected Cost** / Co. A Expected Cost |
| | Company A* | Company B* | |
| 1 | *** | *** | 1.56 |
| 2 | .918 | .812 | 1.38 |
| 3 | .934 | .889 | 1.31 |
| 4 | .946 | .919 | 1.28 |
| 5 | .953 | .936 | 1.25 |
| 6 | .960 | .947 | 1.24 |
| 7 | .964 | .954 | 1.23 |
| 8 | .968 | .960 | 1.22 |
| | **Allocations Based on a 20% Minimum Award Requirement** | | |
| | Bid Year Expected Cost / Prior Year Expected Cost | | Co. B Expected Cost** / Co. A Expected Cost |
| | Company A* | Company B* | |
| 1 | *** | *** | 1.56 |
| 2 | .896 | .883 | 1.54 |
| 3 | .921 | .919 | 1.54 |
| 4 | .937 | .937 | 1.54 |
| 5 | .948 | .948 | 1.54 |
| 6 | .955 | .956 | 1.54 |
| 7 | .958 | .961 | 1.54 |
| 8 | .965 | .966 | 1.54 |

* data from this column is depicted in Fig. 3.1.

** data from this column is depicted in Fig. 312.

*** no prior year competition

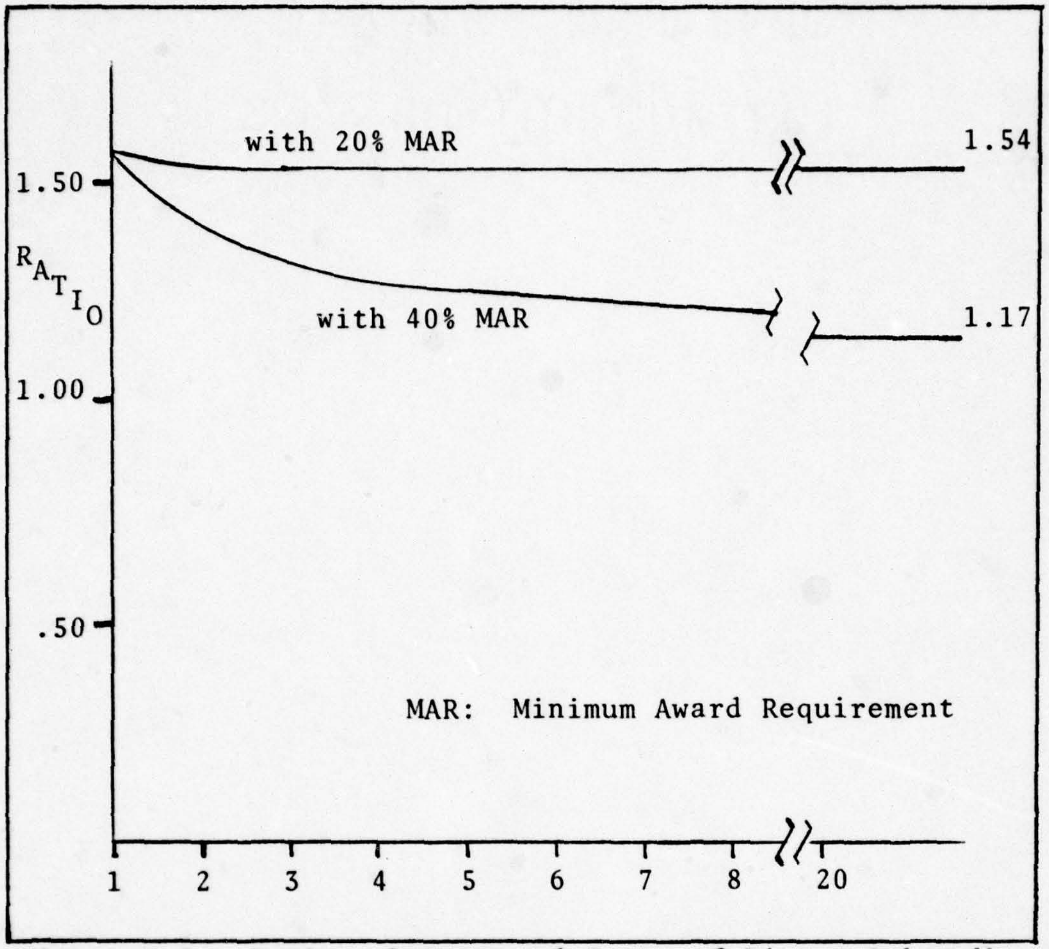



Figure 3.2. Ratio of Expected Costs of Direct Labor Man-hour Requirements - Company B to Company A

beginning of the competition, and the allocations awarded during the competition, are not equal, the ratio of the competitors' expected costs will become almost constant at some point. For both of the cases shown in Fig. 3.2, the ratios change less than 0.0003 between the 20th and 21st years of competition.

## Use of Ratios in the Proposed Allocation Technique

The previous section of this report demonstrated the advantage which Company A receives as a result of production experience gained prior to the beginning of competition with Company B. The greater the amount of prior production experience held by Company A, the greater the resulting advantage. In order to encourage active price competition, some method must be used which will compensate for the disadvantage faced by Company B. And, at the same time, the unit line price bids of the competitors should be maintained as the most significant factor on which to base the competition.

There are two methods available for comparing the unit line price bids of the competing contractors. The first method measures the magnitude of the difference between bids by subtracting the lower of the unit line price bids from the higher bid. This method gives no indication of the relative difference between the bids. For example, the difference of one dollar between a bid of four dollars and a bid of five dollars would be treated the same as the difference between a bid of ninety dollars and a bid of ninety-one dollars. This is so even though in the first case the one dollar represents a difference of 20% between the two bids. In the second case, the one dollar represents a difference of only 1.1%.

The second method of comparing the two bids gives the relative difference, but no the amount of the difference.

This method expresses one bid in terms of the other by using either percentages or ratios as a means for stating the results of the comparison. For the previous example, the bid of four dollars would be stated as a bid of 80% of, or .80 times, the bid of the other competitor. The ninety dollar bid would be stated as a bid of 98.9% of, or .989 times, the bid of the other competitor.

The second method of comparison is more appropriate for the type of allocation problem under consideration. The reason for this is the possibility of one competitor having an experience advantage in production. Should this be the case, the magnitude of the difference between bids would be less indicative as a measure of the competitive performance of the contractors. As demonstrated earlier, the ratio of the competitive bids will, at some point, become almost constant. However, as the direct labor man-hour requirements continue to decrease, the magnitude of the difference between bids will also continue to decrease.

For example, Company A might submit a bid of $100 for an item in one year, and a bid of $90 for that same item the following year. Company B, on the other hand, might submit competing bids of $200 and $190 for the same items during the same two years. If the magnitude of the difference between bids were to be used as a measure of the competitive performance of these companies, the companies would appear to be equal. The difference between competing bids would be $100 the first year, and $100 the second year. If the

judgement of competitive performance were made by comparing the magnitude of the decrease by each competitor the second year, they would again seem to be equally competitive because both bids decreased by $10 the second year. However, the $10 decrease by Company A was a 10% decrease, whereas the $10 decrease by Company B was only a 5% decrease. For any year of the competition, Fig. 3.1 shows that Company B should have a larger percent decrease in bid price than should Company A. It is the comparison of the relative difference, not the magnitude of the difference, which properly indicates that Company A performed more competitively.

Relative differences and relative changes used in the proposed allocation technique will be expressed as ratios using one decimal quantity. For example, the ratio 3:1 will be given as 3, or the ratio 1:3 will be given as .333. Ratios will be used to compare the unit line price bids of the competitors on both a competitor-to-competitor basis, and an individual contractor year-to-year basis.

An added advantage of the use of ratios is that they may be represented by the slope of a line. This will greatly facilitate the explanation of how the proposed allocation technique operates.

Need for Variable Allocations

In the previous sections of this report all annual allocations have been made based on a minimum award requirement for either competitor. The competitor submitting the higher bid has been awarded the minimum award requirement (MAR) allocation for that year. The competitor submitting the low bid has been awarded the balance of the annual procurement as an allocation for that year.

On the surface this may appear to be a minimum cost technique for the procuring agency to use in awarding the annual allocations. By using this technique, the agency buys only the minimum number required at the higher bid price, and the balance of the annual requirement at the lower price. Even though it does work well in the short run, this technique may offer little or no long run incentive for either competitor to reduce his prices. There may even be an incentive for the competitors to raise prices. This can be demonstrated with the use of a curve representing the demand for the output of the competitors as a function of the unit line price bids of both competitors.

A typical demand curve is shown in Fig. 3.3. The vertical axis represents the contractor's unit line price bid, or price per unit ($/q). The horizontal axis represents the number of units demanded (Q). And the demand curve, line DC, represents the relationship between price and the quantity demanded. The demand curve in Fig. 3.3 is normal in

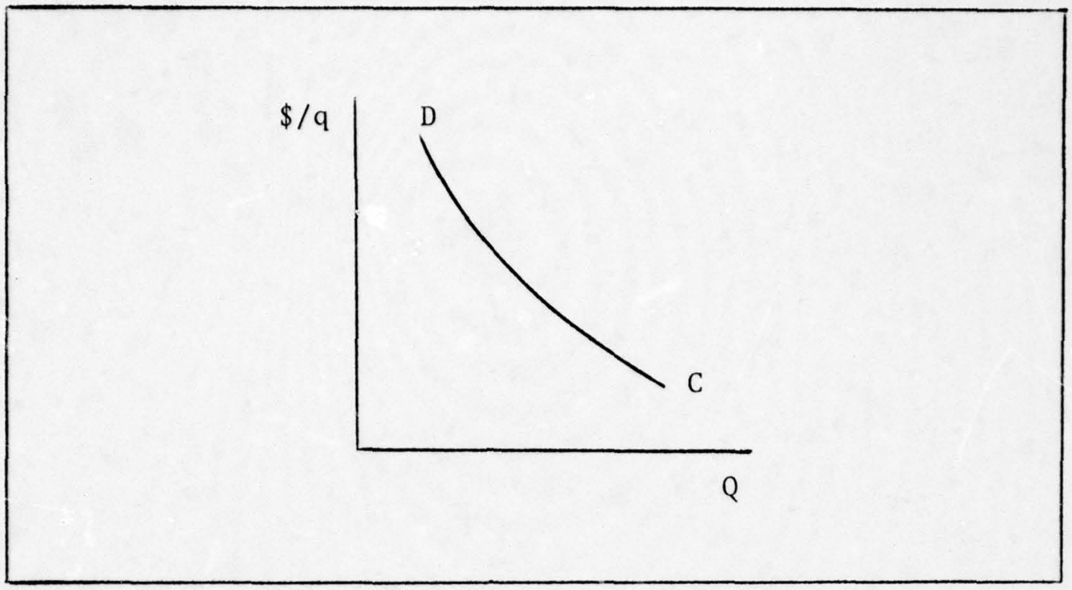



Figure 3.3. Normal Demand Curve

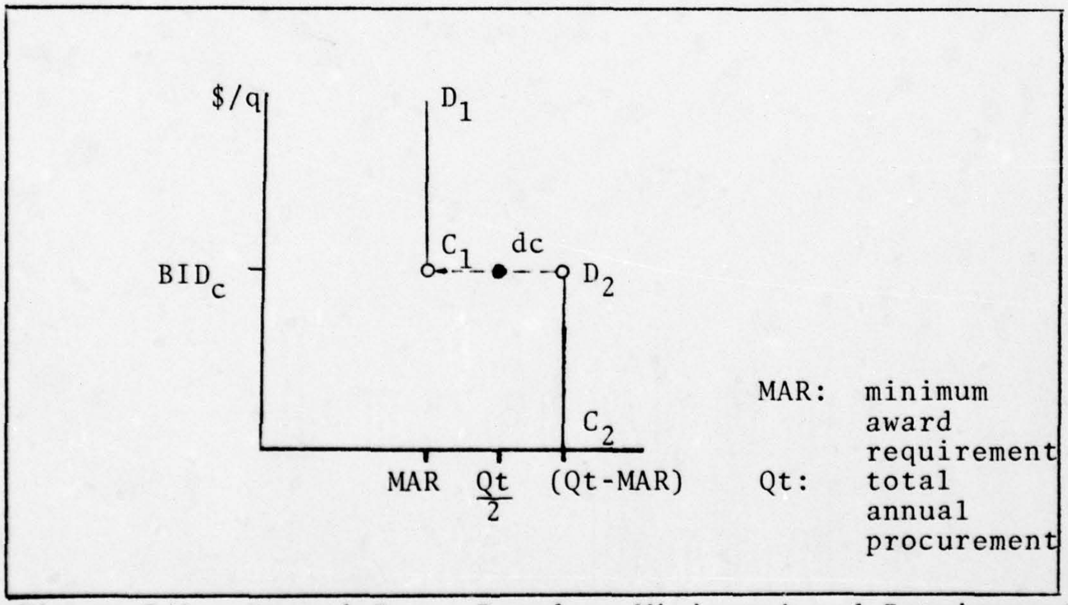



Figure 3.4. Demand Curve Based on Minimum Award Requirements

that "demand curves almost always slope downward to the right" (Ref 9:95). The relationship depicted by this demand curve is that, as price decreases, the number of units demanded increases.

The curve in Figure 3.4 shows the demand for the output of either contractor when the allocations are awarded on the basis of a minimum award requirement (MAR) for the competitor who submits the higher unit line price bid. The vertical and horizontal axes are the same as those in Fig. 3.3. But, the demand curve is now a combination of lines $D_1C_1$ and $D_2C_2$, and the point dc. There is an additional point, $BID_c$, which is labeled on the vertical axis. This point is the unit line price bid submitted by the competitor of the contractor for whom the demand curve is depicted.

The demand curve in Fig. 3.4 shows that at any price above $BID_c$, the amount of output demanded from the contractor is the MAR. At a price which is equal to $BIC_c$, the demand for the contractor's output is $\frac{Qt}{2}$, where $\frac{Qt}{2}$ is one half the total annual procurement requirement. And, at any price below $BID_c$, the demand for the output of the contractor is $(Q_t\text{-MAR})$.

The possible incentive to increase prices, or the lack of an incentive to decrease prices, stems from the allocation of fixed quantities, MAR and $(Q_t\text{-MAR})$, to the competitors who submit the high and low bids respectively.

There are three possible prices (H1, H2, and H3) shows for

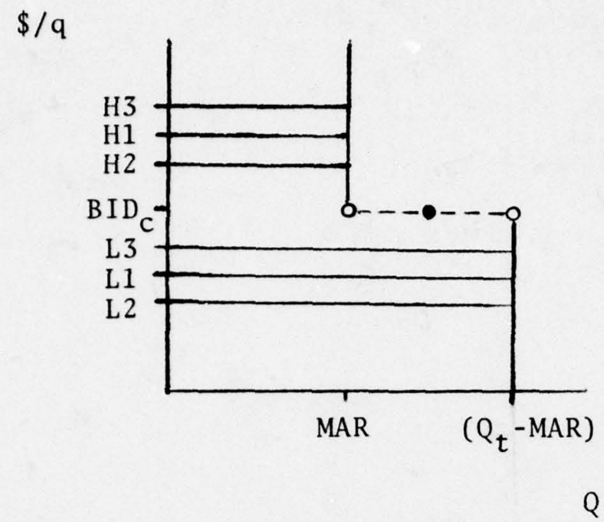



Figure 3.5. Alternative Bids with Same Allocation

the competitor submitting the higher bid, and three prices (L1, L2, and L3) shown for the competitor submitting the lower bid. See Fig. 3.5. These prices will be used to demonstrate the lack of incentive for the competitiors to decrease their unit line price bids when an allocation is made based on MAR allocation techniques.

In the case of the high bidder, Company B from previous examples, the price at $BID_c$ would be the bid submitted by Company A. Assuming that the prior year price charged by Company B was H1, what are the incentives now to change bids to either H2 or H3, or to remain at H1? In order to restrict Company B's alternatives to prices above $BID_c$, it is also assumed that Company A's production experience advantage is large enough to allow Company A's price at $BID_c$ to be less than Company B's cost.

Company B has three alternatives from which to choose: 1) maintain the price at H1; 2) decrease the price to H2; or, 3) raise the price to H3. During the upcoming procurement, Company B's direct labor man-hour requirement will decrease by $100 due to the effects of the learning factor. All other costs for Company B will remain constant at the level of the prior year.

If Company B maintains the price at H1, the profit this year will be $100 greater than that for the prior year. If the price charged by Company B is decreased to H2, then the profit for this year would be less than that for the prior year by the amount [((H1-H2) x MAR) - $100]. And, by increasing the price to H3, profit would increase by the amount [((H3-H1) x MAR) + $100].

Listing the alternative prices in descending order of profitability shows that the higher the price, the greater the profit. As a result, the incentive is for Company B to follow a pricing policy which is exactly opposite the intended purpose of the competitive procurement.

An analysis of the pricing alternatives available to Company A, the low bid competitor, reveals the same order of profitability. In descending order of profitability, Company A's alternatives are L3, L1, and L2. Again, the incentive is for the contractor to raise prices, as long as he remains below $BID_c$.

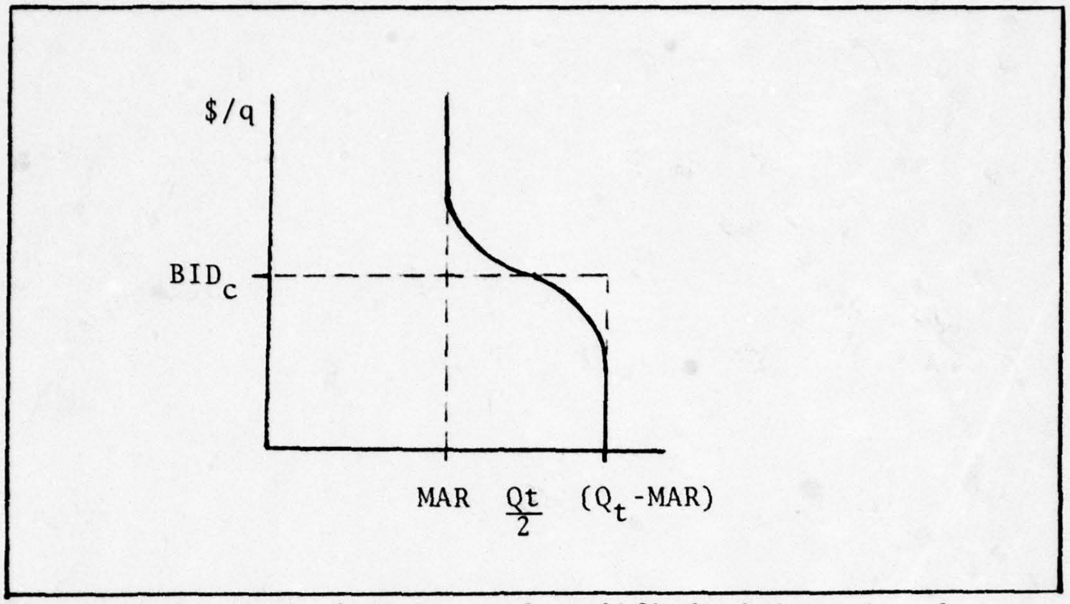



Figure 3.6. Demand Curve with Modified Minimum Award Requirement Allocations

The incentive to raise prices is a direct result of the fact that the demand curve depicted in Fig. 3.4 and Fig 3.5 is inelastic, both above and below $BID_c$. "The responsiveness of the quantity demanded to a change in the price (with the demand schedule unchanged) is called the elasticity of demand" (Ref 6:68). This elasticity is measured by the ratio of the percent change in quantity demanded to the percent change in price.

The lack of incentive for the competitors to reduce prices can be reversed, in part, by changing the demand curve in such a way as to increase the elasticity of demand. In order to do this, the fixed-quantity MAR allocations for the high and low bidders must be changed to variable-quantity allocations which are some function of price. This requires

that modifications be made to the MAR allocation technique used thus far in the report. A possible demand curve resulting from the necessary modifications to the MAR allocation technique is shown in Fig. 3.6. The minimum allowable allocation to be awarded either contractor is maintained at MAR, and the maximum allowable, maintained at ($Q_t$-MAR). However, allocations may now be made at points between the minimum and maximum allocations. The new demand curve has been constructed such that, as the ratio of the competitive bids approaches 1.00, the elasticity increases to its maximum value. As the ratio of the bids moves away from 1.00, in either direction, the elasticity decreases. The elasticity decreases to its minimum value of 0.00 as the demand curve intersects either the minimum or maximum allowable allocations.

The following reasoning was used in constructing the new demand curve. By making it possible for Company B to receive allocations greater than the MAR allocation, the advantage afforded Company A by its prior production experience is decreased. Under the new demand schedule, the experience advantage can be eliminated in a much shorter time period if the proposed allocation technique properly compensates Company B for its initial disadvantage. The ratio of the unit line price bids of one competitor to those of the other competitor would become 1.00 with the elimination of the experience advantage. Here again, the assumption has been

made that all factors are equal for both competitors. In order to encourage the greatest degree of competition, the point of maximum elasticity is positioned to coincide with the expected ratio of the competitors' unit line price bids. The elasticity decreases to zero as the demand curve approaches the MAR allocations. This prevents the awarding of allocations beyond the limits for either the high or low bidder under the MAR allocation method.

### Compensating for Initial Difference in Production Experience

As discussed earlier in this chapter, Company B immediately finds itself at a competitive disadvantage when Company A has had prior production experience. If the proposed allocation technique is to follow the principle that superior competitive performance is rewarded, and inferior performance penalized, then some means must be devised whereby Company B will be compensated for the difference in production experience. Without some means of compensation, Company B is automatically penalized by being placed at a competitive disadvantage regardless of its performance.

The ratios of direct labor costs, as listed in Table V and depicted in Fig. 3.1, show that if the ratios of year-to-year expected direct labor costs for each competitor were used as a competitive factor, then Company B could have the competitive advantage. Because this possible advantage and the production experience disadvantage decrease over the same time period, it is possible to compensate Company B by

including the year-to-year cost ratios as factors of the annual procurement competition.

The method used to include the year-to-year cost ratios is to adjust the annual unit line price bids of the competitors. This adjustment is accomplished by multiplying the unit line price bids times the respective competitor's annual ratio. These adjusted unit line price bids are computed as:

$$\text{Adjusted Price Bid} = \text{Price Bid (present yr)} \times \frac{\text{Price Bid (present yr)}}{\text{Price Bid (prior yr)}} \tag{3}$$

This method of price bid adjustment, hereafter referred to as Method I, can be demonstrated by using the expected direct labor costs to represent the unit line price bids. Using Method I with the 40% MAR expected costs from Table IV and the year-to-year expected cost ratios from Table V, the adjusted unit line price bids for the second year of competition would be:

Company A

Adjusted Price Bid = \$2,416 X .918

= \$2,218

Company B

Adjusted Price Bid = \$3,337 X .812

= \$2,710

The ratio of Company B's expected costs to those of Company A would now be 1.22, rather than the original 1.38 as listed in Table V. The results of using Method I for the entire competition period covered by Tables IV and V are listed in Table VI. Included in Table VI are the original unadjusted cost ratios. A comparison of the contractor-to-contractor cost ratios, with and without compensation to Company B, shows that the effect of Method I decreases over time.

With the 40% MAR allocation, Company B's expected costs for the second year decreased from 1.38 times Company A's costs, without compensation, to 1.22 times Company A's costs, with compensation. This is a decrease of 42.1% in the difference between the two contractors' costs when Company B is compensated for the difference in prior production experience. By the eighth year, the ratio of Company B's expected costs to those of Company A decreases from 1.22 without compensation, to 1.21 with compensation. This is only a 4.5% decrease in the difference of expected costs. This decreasing effect of the compensation for Company B is appropriate in that the ratio of Company A's production experience to that of Company B also decreases as the total number of units produced increases.

Repeating the same comparison under the 20% MAR allocation shows that the cost ratio in year two decreases from 1.54 to 1.52. This is a 3.7% reduction in the difference

Table VI

Adjusted Cost Ratios Using Method I

| Year | Allocations Based on a 40% MAR | | | |
|---|---|---|---|---|
| | Adjusted Costs | | Ratio: Co. B to Co. A | |
| | Company A | Company B | Adjusted | Unadjusted |
| 1 | ** | ** | ** | 1.56 |
| 2 | $2,218 | $2,710 | 1.22 | 1.38 |
| 3 | 2,105 | 2,637 | 1.25 | 1.31 |
| 4 | 2,019 | 2,505 | 1.24 | 1.28 |
| 5 | 1,938 | 2,388 | 1.23 | 1.25 |
| 6 | 1,874 | 2,288 | 1.22 | 1.24 |
| 7 | 1,814 | 2,199 | 1.21 | 1.23 |
| 8 | 1,763 | 2,124 | 1.21 | 1.22 |
| | Allocations Based on a 20% MAR | | | |
| 1 | ** | ** | ** | 1.56 |
| 2 | $2,113 | $3,204 | 1.52 | 1.54 |
| 3 | 2,000 | 3,069 | 1.53 | 1.54 |
| 4 | 1,906 | 2,931 | 1.54 | 1.54 |
| 5 | 1,828 | 2,811 | 1.54 | 1.54 |
| 6 | 1,754 | 2,710 | 1.54 | 1.54 |
| 7 | 1,691 | 2,620 | 1.54 | 1.54 |
| 8 | 1,646 | 2,543 | 1.54 | 1.54 |

** not calculated because there is no prior year for Company B

between the price bids of the competitors. At the eight year point, the reduction of the difference in price bids is 0%.

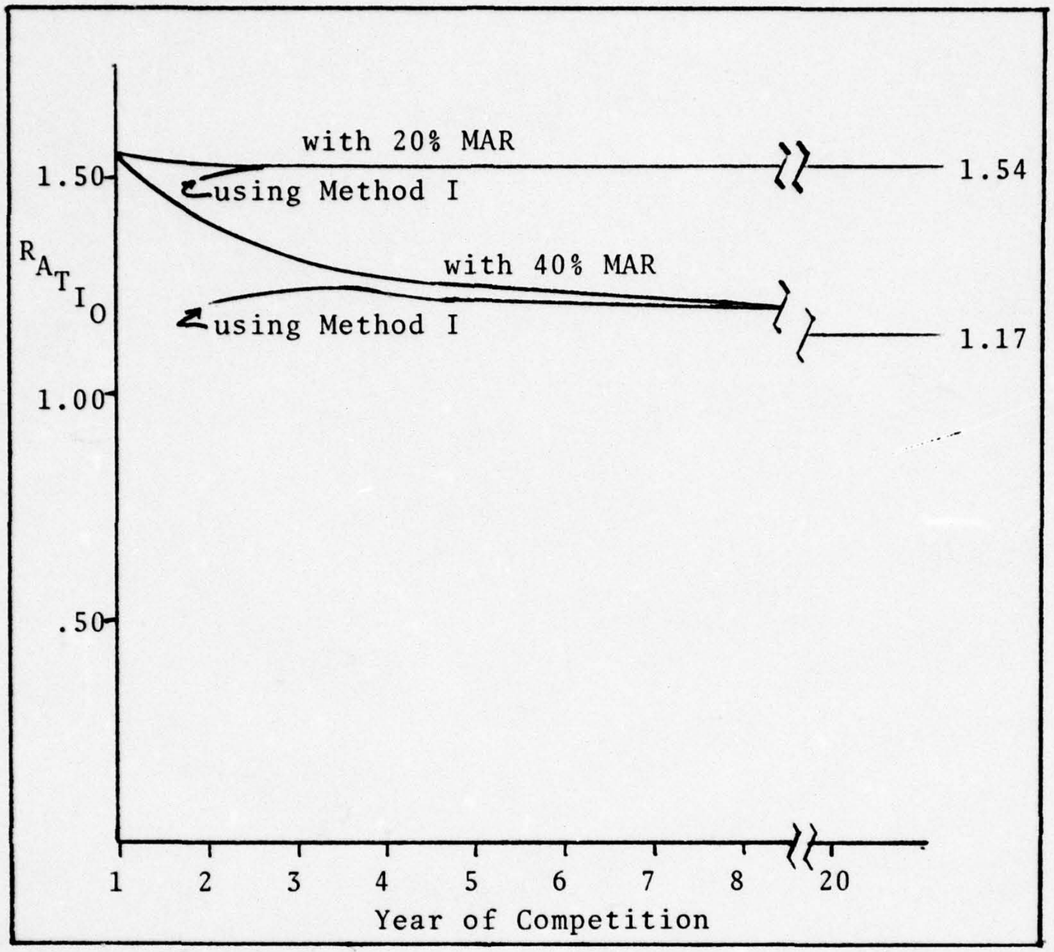



Figure 3.7. Ratio of Expected Costs Using Method I for Compensation

This adjustment method cannot be used to compensate Company B during the first year of the competition. This is due to the fact that Company B would have no prior year price bid with which to compute the necessary price ratio. The effect of using Method I is demonstrated in Fig. 3.7. Allocations for the first year could be based on any method deemed appropriate by the procuring agency.

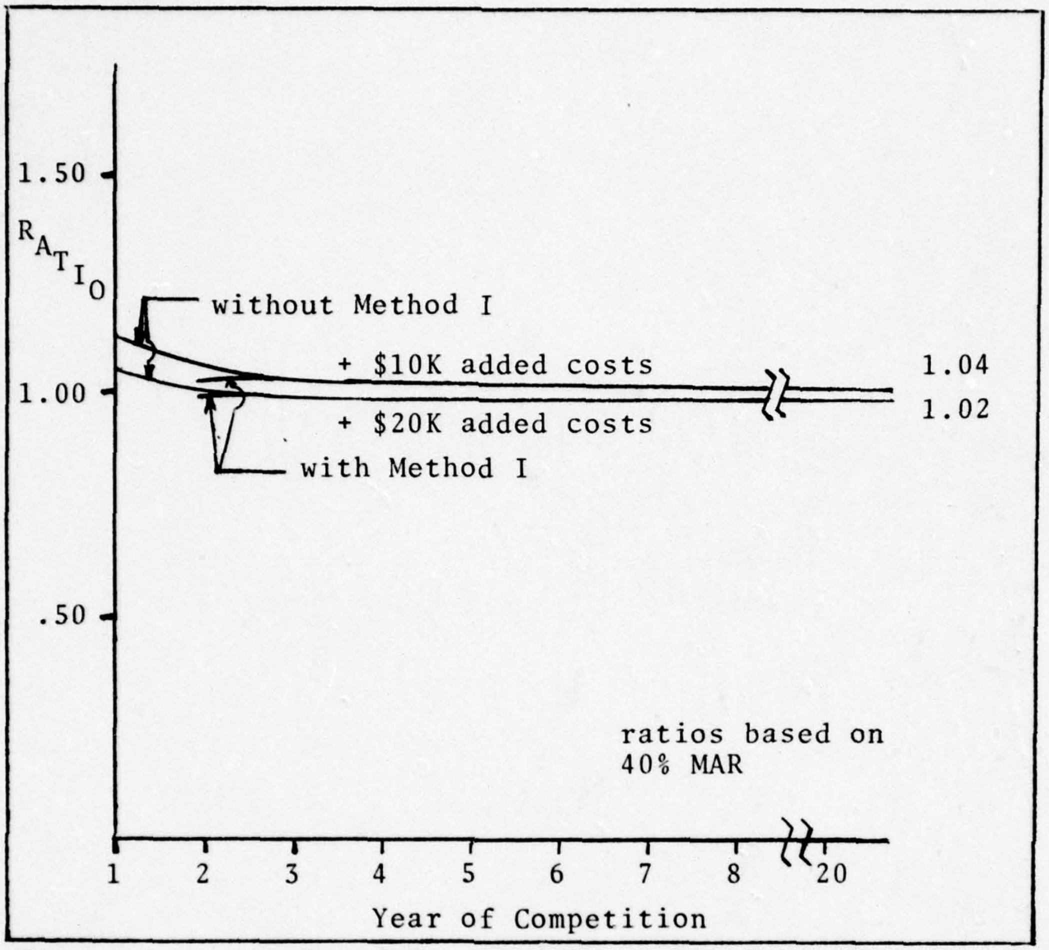



Figure 3.8. Ratio of Expected Unit Line Price Bids (I)

The adjusted cost ratios in Table VI and Fig. 3.7 were computed using the previously computed expected direct labor costs plus profit. This was done so as to simplify the explanation of how Method I is used, and to demonstrate the effect that Method I has on the unit line price bids. However, the use of direct labor costs to represent unit line price bids distorts the magnitude of the effect of

Table VII

Expected Bud Ratios Using Method I*

| Year | Expected Bud Including $10K Added Costs | | |
|---|---|---|---|
| | Unadjusted Bids | | |
| | Company A | Company B | Ratio: Co. B to Co. A |
| 1 | $12,632 | $14,112 | 1.12 |
| 2 | 12,416 | 13,337 | 1.07 |
| 3 | 12,257 | 12,966 | 1.06 |
| 4 | 12,134 | 12,726 | 1.05 |
| 5 | 12,034 | 12,551 | 1.04 |
| 6 | 11,952 | 12,416 | 1.04 |
| 7 | 11,882 | 12,305 | 1.04 |
| 8 | 11,821 | 12,213 | 1.03 |
| | Adjusted Bids | | |
| 1 | ** | ** | ** |
| 2 | $12,205 | $12,603 | 1.03 |
| 3 | 12,095 | 12,603 | 1.04 |
| 4 | 12,013 | 12,484 | 1.04 |
| 5 | 11,938 | 12,375 | 1.04 |
| 6 | 11,868 | 12,279 | 1.04 |
| 7 | 11,811 | 12,194 | 1.03 |
| 8 | 11,762 | 12,115 | 1.03 |
| | *** | | |

* for this illustration all data is based on a 40% MAR

** not calculated because there is no prior year for Company B

*** Table VII is continued on next page for $20K added costs

Method I. This distortion is a result of the fact that the learning factor affects 100% of the total costs used in the

Table VII continued

| Year | Expected Bid Including $20K Added Costs | | |
|---|---|---|---|
| | Unadjusted Bids Company A | Company B | Ratio: Co. B to Co. A |
| 1 | $22,632 | $24,112 | 1.06 |
| 2 | 22,416 | 23,337 | 1.04 |
| 3 | 22,257 | 22,966 | 1.03 |
| 4 | 22,134 | 22,726 | 1.03 |
| 5 | 22,034 | 22,551 | 1.02 |
| 6 | 21,952 | 22,416 | 1.02 |
| 7 | 21,882 | 22,305 | 1.02 |
| 8 | 21,821 | 22,213 | 1.02 |
| | Adjusted Bids | | |
| 1 | ** | ** | ** |
| 2 | $22,192 | $22,590 | 1.02 |
| 3 | 22,098 | 22,599 | 1.02 |
| 4 | 22,023 | 22,499 | 1.02 |
| 5 | 21,924 | 22,371 | 1.02 |
| 6 | 21,864 | 22,282 | 1.02 |
| 7 | 21,816 | 22,193 | 1.02 |
| 8 | 21,756 | 22,124 | 1.02 |

** not calculated because there is no prior year for Company B

explanation. In reality, the learning factor would only decrease those costs resulting from direct labor.

A more accurate description of the impact that Method I has on the unit line price bid ratios is shown by Table VII and Fig. 3.8. In these illustrations the direct labor

costs from the earlier examples represent only a portion of the total unit line price bids. Additional costs of $10,000 and $20,000, including profit, are added to the direct labor costs. With these additional costs included, direct labor represents approximately 20% and 10%, respectively, of the total unit line price bids. This is a much more realistic approximation of the actual cost behavior to be expected during the period of the competitive procurement.

The second method of compensating for the difference in production experience, Method II, is to adjust the unit line price bids by using two year-to-year price ratios. Rather than using only the one ratio of present year price bid to prior year price bid, Method II also includes the year-to-year ratio from the preceding year. Using Method II, the adjusted price bid for year n is computed as:

$$\text{Adjusted Price Bid}_n + \text{Price Bid}_n \times \frac{\text{Price Bid}_n}{\text{Price Bid}_{n-1}} \times \frac{\text{Price Bid}_{n-1}}{\text{Price Bid}_{n-2}} \qquad (4)$$

For the same reason as with Method I, this method cannot be used for the first year of the competition. And, in order to use Method II for the second year of the competition, one modification is made. The ratio of the price bid for year two to the price bid for year one is used twice. After making this modification to Equation 4, the adjusted price bids for the second year, n equals two, would be

computed as:

$$\text{Adjusted Price Bid}_2 = \text{Price Bid}_2 \times \frac{\text{Price Bid}_2}{\text{Price Bid}_1} \times \frac{\text{Price Bid}_2}{\text{Price Bid}_1} \qquad (5)$$

For the second year of the competition, the ratio of the expected costs for Company B to those of Company A is now 1.08, as compared to the 1.38 ratio without compensation, or the 1.22 ratio with Method I. Method II, by using two year-to-year ratios for determining the adjusted price bids, compensates for 78.95% of the prior production experience disadvantage when the allocations are made on a 40% MAR basis.

The results of using Method II for the first eight years of the competitive procurement are listed in Table VIII. These results are based on the same data as that used for Table VI. The effects of Methods I and II on the ratio of Company B's unit line price bids to those of Company A are shown in Fig. 3.9. The effect of adjusting the price bids by using one annual ratio, Method I, and the effect using two annual ratios, Method II, are shown for both the 40% and 20% MAR allocations.

The ratios depicted in Fig. 3.9 were computed using only that portion of the competitors' unit line price bids which is subject to the effects of the learning factor.

Figure 3.10 demonstrates the effect of Method II

Table VIII

Adjusted Cost Ratios Using Method II

| Year | Adjusted Costs Company A | Adjusted Costs Company B | Ratio: Co. B to Co. A Method II | Ratio: Co. B to Co. A Method I |
|---|---|---|---|---|
| | **Allocations Based on a 40% MAR** | | | |
| 1 | ** | ** | ** | ** |
| 2 | $2,036 | $2,178 | 1.08 | 1.22 |
| 3 | 1,930 | 2,139 | 1.11 | 1.25 |
| 4 | 1,885 | 2,227 | 1.18 | 1.24 |
| 5 | 1,835 | 2,194 | 1.20 | 1.23 |
| 6 | 1,786 | 2,141 | 1.20 | 1.22 |
| 7 | 1,741 | 2,083 | 1.20 | 1.21 |
| 8 | 1,699 | 2,027 | 1.19 | 1.21 |
| | **Allocations Based on a 20% MAR** | | | |
| 1 | ** | ** | ** | ** |
| 2 | $1,893 | $2,826 | 1.49 | 1.52 |
| 3 | 1,792 | 2,711 | 1.51 | 1.53 |
| 4 | 1,755 | 2,696 | 1.54 | 1.54 |
| 5 | 1,711 | 2,635 | 1.54 | 1.54 |
| 6 | 1,659 | 2,569 | 1.55 | 1.54 |
| 7 | 1,616 | 2,505 | 1.55 | 1.54 |
| 8 | 1,584 | 2,444 | 1.54 | 1.54 |

** not calculated because there is no prior year for Company B

when costs other than those affected by the learning factor are included in the expected unit line price bids. The same additional costs are used for Fig. 3.10 as were used for Fig. 3.8. Table IX lists for Method II the expected bids and bid

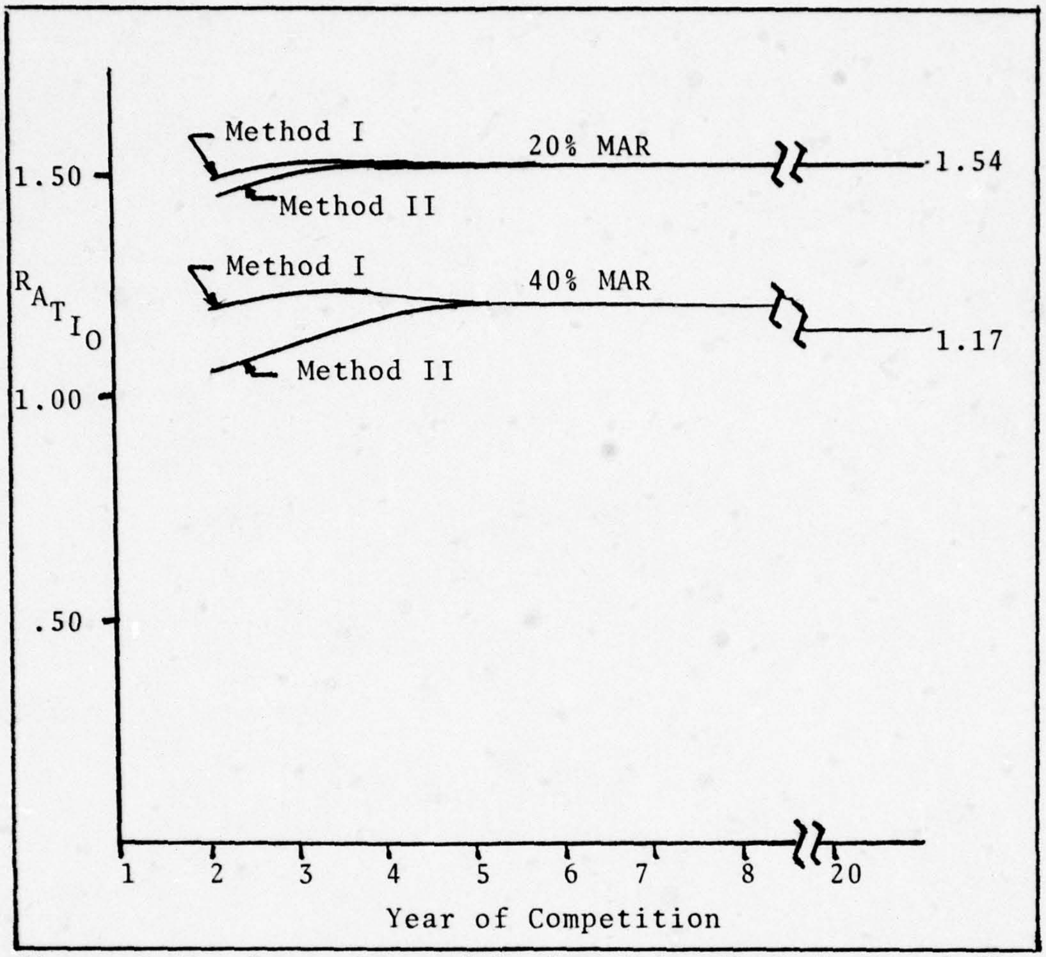


Figure 3.9. Comparison of Ratios Using Methods I and II

ratios when added costs are included in the bids. The data from Fig. 3.10 is expanded in Fig. 3.11 for better illustration.

The difference in adjusted ratios between Method I and Method II is illustrated in Fig. 3.12. Examination of Fig. 3.12 and comparison of the ratios listed in Tables VII and IX demonstrate an important advantage that the use of Method II has over the use of Method I. For competition years two through eight, Method II has average ratios which are 25%

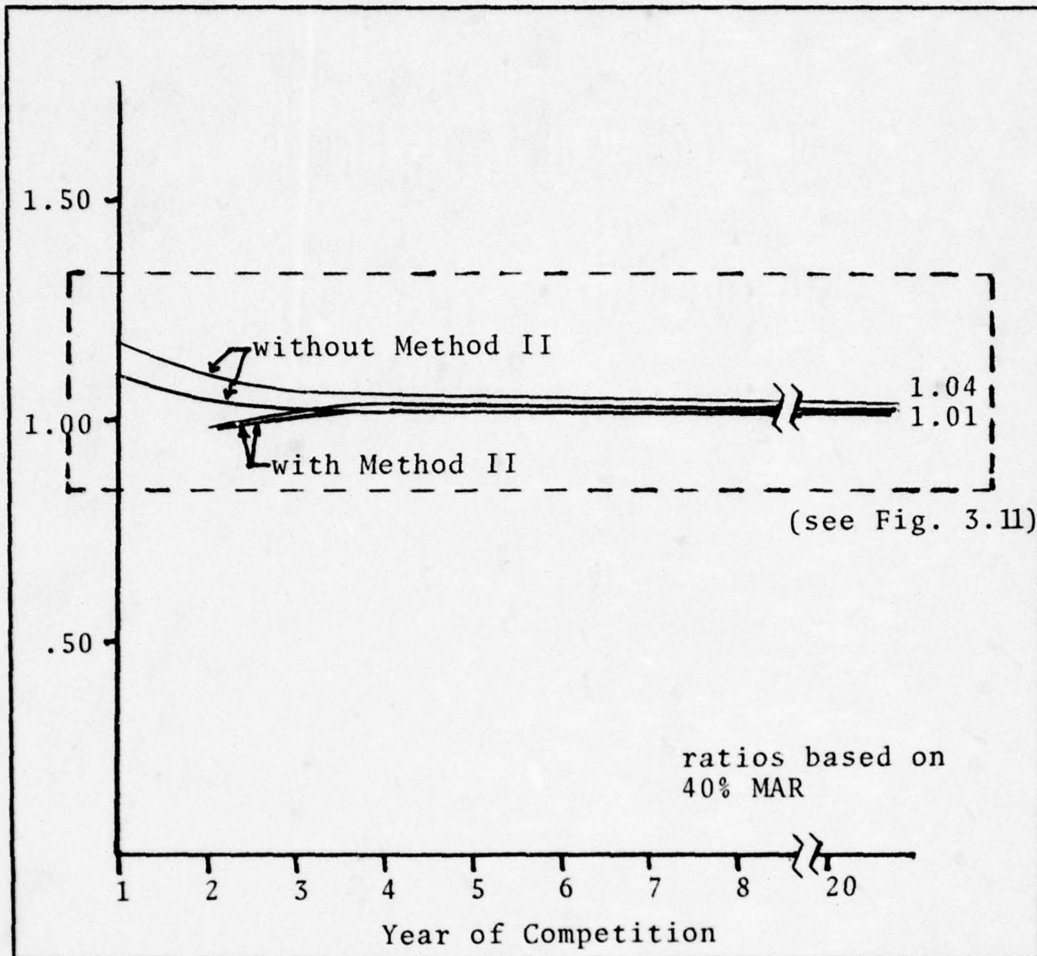


Figure 3.10. Ratio of Expected Unit Line Price Bids (II)

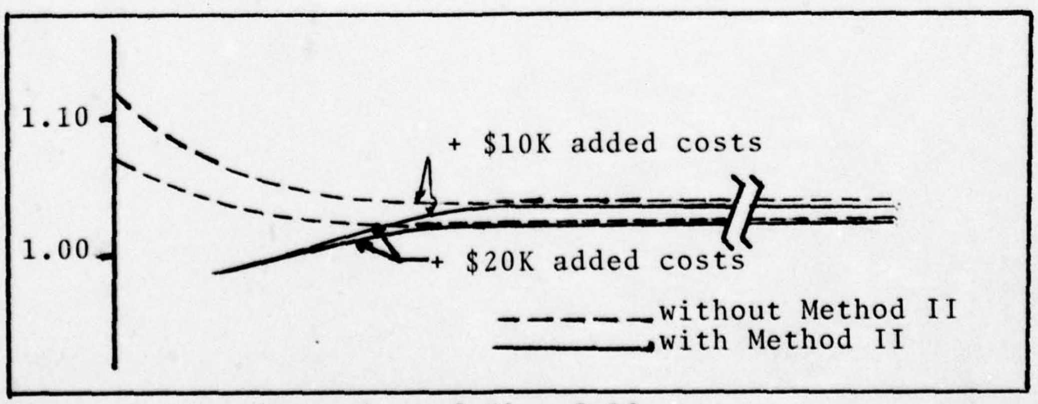


Figure 3.11. Expansion of Fig. 3.10

Table IX

Expected Bid Ratios Using Method II*

| Year | Expected Bids Including $10K Added Costs | | |
|---|---|---|---|
| | Unadjusted Bids Company A | Company B | Ratio: Co. B to Co. A |
| 1 | $12,632 | $14,112 | 1.12 |
| 2 | 12,416 | 13,337 | 1.07 |
| 3 | 12,257 | 12,966 | 1.06 |
| 4 | 12,134 | 12,726 | 1.05 |
| 5 | 12,034 | 12,551 | 1.04 |
| 6 | 11,952 | 12,416 | 1.04 |
| 7 | 11,882 | 12,305 | 1.04 |
| 8 | 11,821 | 12,213 | 1.03 |
| | Adjusted Bids | | |
| 1 | ** | ** | ** |
| 2 | $12,024 | $11,912 | 0.99 |
| 3 | 11,893 | 11,913 | 1.00 |
| 4 | 11,849 | 12,143 | 1.02 |
| 5 | 11,815 | 12,149 | 1.03 |
| 6 | 11,773 | 12,114 | 1.03 |
| 7 | 11,732 | 12,064 | 1.03 |
| 8 | 11,691 | 12,013 | 1.03 |
| | *** | | |

* for this illustration all data is based on a 40% MAR

** not calculated because there is no prior year for Company B

*** Table IX is continued on next page for $20K added costs

and 50% closer to a ratio of 1.00 for the +$10K and +$20K added costs respectively. But, even more important is the

Table IX continued

| Year | Expected Bids Including $20K Added Costs | | |
|---|---|---|---|
| | Unadjusted Bids Company A | Company B | Ratio: Co. B to Co. A |
| 1 | $22,632 | $24,112 | 1.06 |
| 2 | 22,416 | 23,337 | 1.04 |
| 3 | 22,257 | 22,966 | 1.03 |
| 4 | 22,134 | 22,726 | 1.03 |
| 5 | 22,034 | 22,551 | 1.02 |
| 6 | 21,952 | 22,416 | 1.02 |
| 7 | 21,882 | 22,305 | 1.02 |
| 8 | 21,821 | 22,213 | 1.02 |
| | Adjusted Bids | | |
| 1 | ** | ** | ** |
| 2 | $21,990 | $21,861 | 0.99 |
| 3 | 21,888 | 21,874 | 1.00 |
| 4 | 21,856 | 23,131 | 1.01 |
| 5 | 21,813 | 22,143 | 1.02 |
| 6 | 21,771 | 22,110 | 1.02 |
| 7 | 21,731 | 22,062 | 1.02 |
| 8 | 21,691 | 22,012 | 1.01 |

** not calculated because there is no prior year for Company B

fact that during competition years two through five, when the difference in production experience is greater, the average ratios are 67% and 50% closer to 1.00 when Method II is used rather than Method I. Another advantage of the use of Method II is that the inclusion of more than one

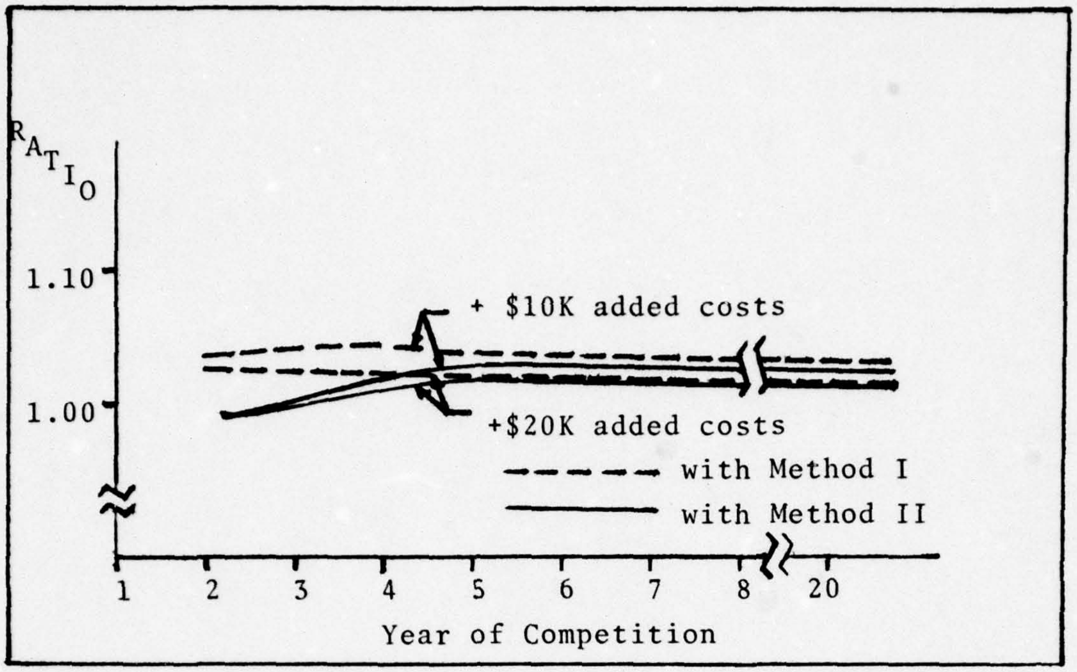



Figure 3.12. Comparison of Methods I and II with Added Costs

year-to-year ratio in the adjustment method makes it more advantageous for either competitor to lower the unit line price bids at the earliest opportunity. A further explanation of this advantage will be given later in this report.

Method II, because of the aforementioned advantages, is the method which is used to compensate for the production experience disadvantage of Company B in the proposed allocation technique.

## Contractor Bidding

The unit line price bids solicited from the competing contractors must cover the entire range of possible allocations. This differs greatly from what could be considered the normal competitive procurement--one in which each of the contractors bids a certain price for a specific quantity of procurement items. In the special type of procurement under consideration, the competitors do not know, at the time of bidding, the exact number of items each will provide. This information is not known until after the bids are evaluated and the allocations awarded. However, the magnitude of the total procurement is known in advance, as well as any MAR allocation requirements. The bidding technique used in such a procurement situation must meet two requirements. First, the bidding technique must provide some means by which each contractor can submit a valid bid for whatever quantity he is finally allocated. And second, there must be some means by which each of the competitor's bids can be translated into a single number for use in computing the overall competitive indices described in Chapter II of this report.

A seemingly obvious solution to the first requirement would be to have each of the competitors submit a bid for each of the possible allocation quantities. However, this solution would be rather cumbersome since the proposed allocation technique is designed for large quantity procurements.

And the large number of individual items involved (in the A-10 30mm ammunition case, millions of items) could require an equally large number of individual bids. The actual number of bids required would be a function of the total number of items to be procured, any predetermined MAR allocations, and the number of decimal places used for the final allocation percentages. In order to reduce the number of individual quantity bids, the following method is proposed for contractor bidding.

## Proposed Bidding Method

The proposed bidding method requires only a small number of bids by each of the competing contractors. By soliciting unit line price bids for a representative number of allocation levels, unit line prices for intermediate allocations can be determined by regression analysis. Using this method, the required number of bids per contractor may be reduced to as few as four or five. For demonstration purposes, five unit line price bids per contractor will be used.

The levels for which bids are required are determined by dividing that portion of the total procurement quantity not subject to MAR restrictions into (n-1) equal portions, where $\underline{n}$ is the number of bids solicited from each competitor. Bids would be solicited for the MAR, 100%-MAR, and (n-2) intermediate allocation levels.

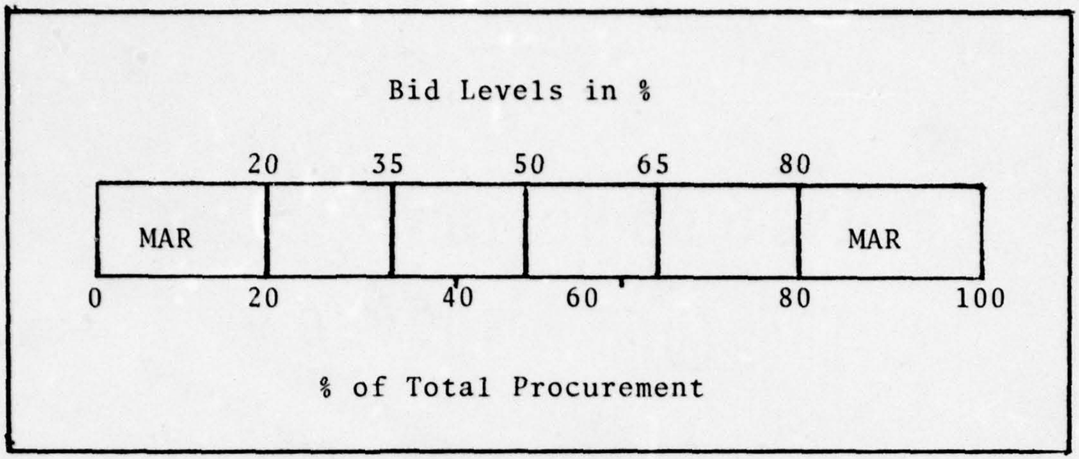



Figure 3.13. Bid Levels with a 20% MAR

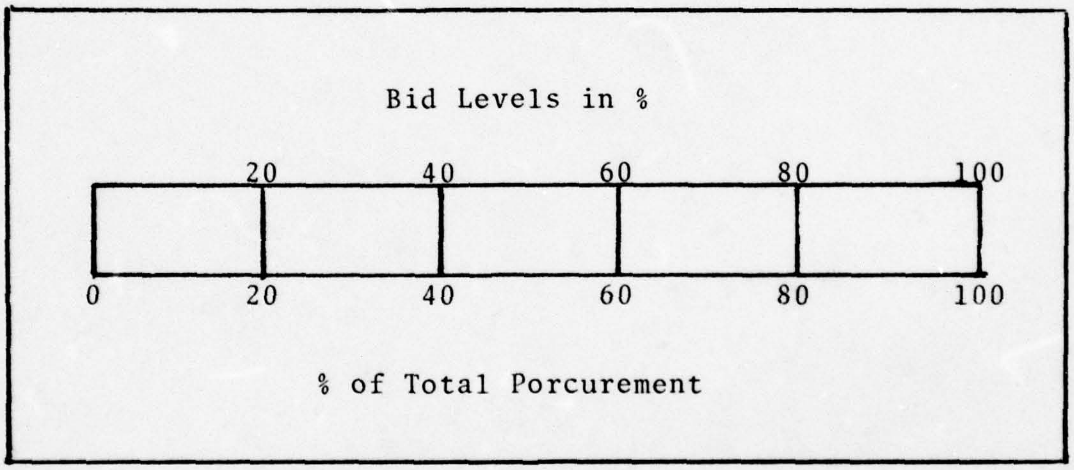



Figure 3.14. Bid Levels without MAR Restrictions

Figure 3.13 depicts the bid levels for five bids with a 20% MAR restriction on the allocations. The lowest level for which a bid is submitted is, therefore, 20% and the highest bid level is 80% (100% - MAR). The three (n-2) intermediate bid levels are evenly spaced between the lowest and highest bid points. Each contractor would submit bids based on the

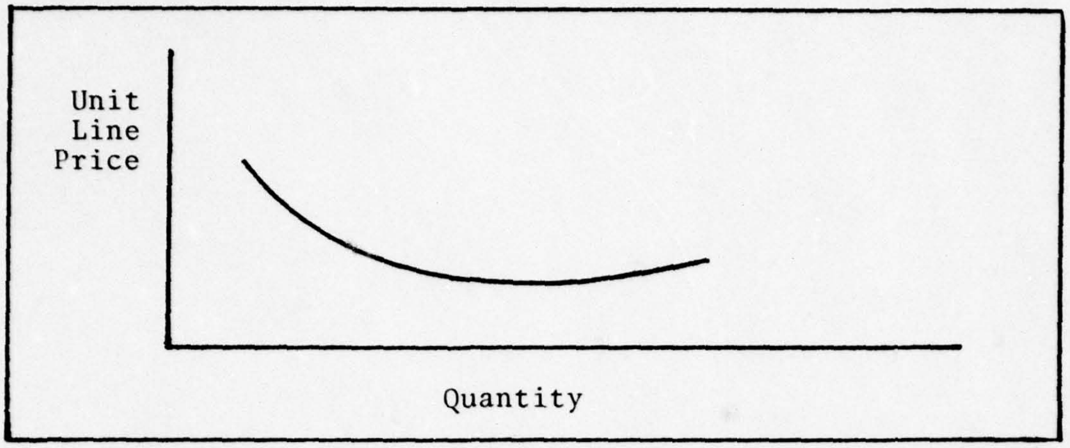



Figure 3.15. Unit Line Price vs Quantity

price per unit for allocation levels of 20, 35, 50, 65, and 80% of the total procurement quantity.

Figure 3.14 depicts the bid levels for five bids with no MAR restrictions. For this particular case, the total procurement would be divided into five (n) equal portions. No bid would be solicited for the 0% allocation level.

Because the bids are based on the unit line price, which is the cost-per-unit or average cost, at each of the various bid levels, an approximation can be made of the general relationship of the bids for either contractor. Figure 3.15 depicts this relationship.

There are certain economies of scale which allow the average price per unit to decrease as the quantity produced increases. At some point in production, however, diseconomies of scale may cause the average cost to start increasing as the quantity produced continues to increase. Without going into a detailed discussion of short-run and long-run

average cost curves, economies and diseconomies of scale, and comparisons of the different ranges of output within different industries for which the average cost declines with increasing quantity, the assumption is made that the average costs for these competitors will decrease at a decreasing rate as the quantity increases until a point is reached at which the average cost may begin to increase at an increasing rate (Ref 9:154-194). The actual relationship for Fig. 3.15 is further assumed to be some form of a smooth curve--either exponential, logarithmic, or quadratic.

Through the use of regression analysis, a curve can be fitted to the actual bids of either contractor. This curve should give an approximation which is sufficiently accurate for comparison of the competing bids of the contractors. This curve can also be used to determine unit line prices for any allocation level for which a specific bid is not solicited. In order to reduce the bids of either contractor to a single number, the average bid for each competitor is calculated using the fitted curve.

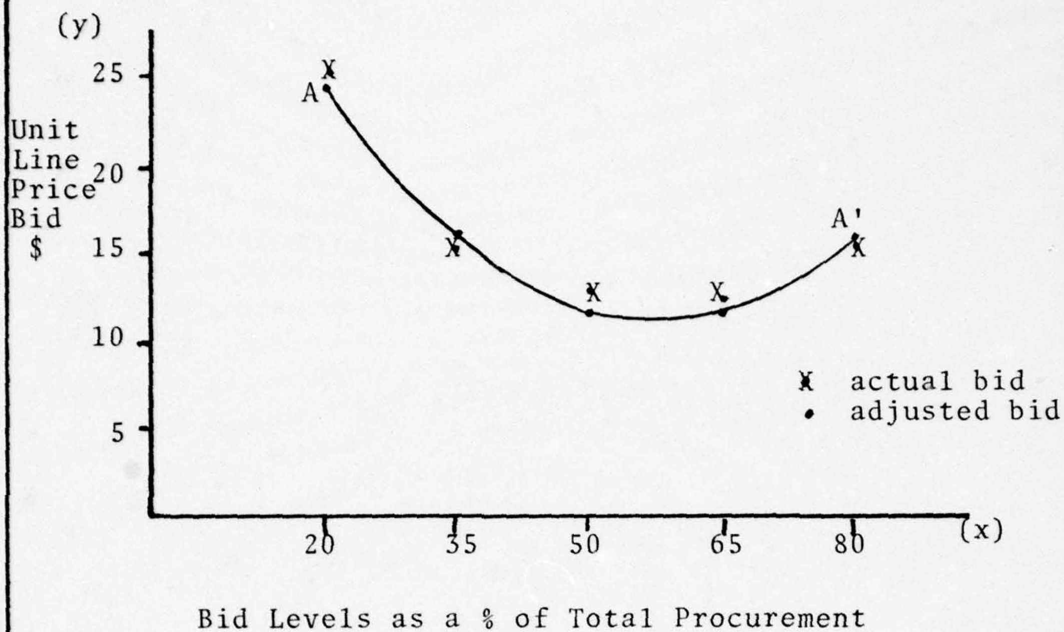
Consideration was given to the use of an averaging technique similar to that for determining expected times in the Program Evaluation and Review Technique (PERT). With PERT the most likely value is weighted four times as great as the extreme values when computing the expected time required for an activity (Ref 5:19). The use of such a technique was considered as an additional means of reducing the chances of

either competitor submitting artificially high or low bids. This was determined to be unnecessary because there already are inherent risks associated with the use of bids which are either higher or lower than what they would be using a normal cost plus profit bid determination.

Either competitor may decide that he knows enough about his competitor's costs that he can closely predict the final allocations, even before the actual bid submission. Given such a situation, a competitor may be tempted to raise his bid for the allocation level he expects to receive. This artificially high bid could then be offset by submitting artificially low bids for the levels he does not expect to receive. The risk associated with this strategy is that the artificially high bid could be great enough to push the allocation for this bidder down to an allocation level which has been bid artificially low. Should this happen, the bidder would then be required to provide his allocated quantity at a unit line price which is less than the normal cost plus profit.

Figure 3.16 illustrates the proposed bidding technique using the bid levels from Fig. 3.13. The bids at each of the five bid levels are: \$25.00 per unit for a 20% allocation, \$15.00 for 35%, \$14.50 for 50%, \$12.00 for 65%, and \$15.00 for 80%. The line AA' has been calculated by quadratic regression. The quadratic equation

$$Y = a_2x^2 + a_1x + a_o \qquad (6)$$




| Bid Level | 20% | 35% | 50% | 65% | 80% |
|---|---|---|---|---|---|
| Actual Bid | $25.00 | $15.00 | $12.50 | $12.00 | $15.00 |
| Adjust Bid | 24.50 | 16.20 | 11.90 | 11.60 | 15.30 |

Adjusted Bid Average $14.57

Line AA':

$$y(x) = 0.00888889x^2 - 1.04222222x + 41.78888889$$

Figure 3.16. Bid Adjustment by Quadratic Regression

with normal equations

$$\sum_{i=1}^{n} y_i = a_2 \sum_{i=1}^{n} x_i^2 + a_1 \sum_{i=1}^{n} x_i + a_0 n \tag{7}$$

$$\sum_{i=1}^{n} x_i y_i = a_2 \sum_{i=1}^{n} x_i^3 + a_1 \sum_{i=1}^{n} x_i^2 + a_0 \sum_{i=1}^{n} x_i \tag{8}$$

$$\sum_{i=1}^{n} x_i^2 y_i = a_2 \sum_{i=1}^{n} x_i^4 + a_1 \sum_{i=1}^{n} x_i^3 + a_0 \sum_{i=1}^{n} x_i^2 \tag{9}$$

where $\underline{y}$ is the unit line price bid, $\underline{x}$ is the allocation bid level as a percent of total procurement, and $\underline{n}$ is the number of bid levels, is used to approximate the unit line price bid at any allocation level. The adjusted bids used for the allocation competition are then determined by the equation

$$y(x) = a_2x^2 + a_1x + a_0 \tag{10}$$

(Ref 11:58-63)

The average bid for each contractor is then calculated by first integrating Equation 10 over the interval from the lowest bid level to the highest bid level, and then dividing by the length of the interval.

The use of this bidding technique meets both of the previously stated requirements. Unit line prices for any allocation level can be determined by the use of Equation 10. And the average bid figure computed for each competitor can then be used to compute the overall competitive indices described in Chapter II of this report.

## Determination of Contractor Allocations

The final determination of the allocations to be awarded each of the competitors is based on the ratio of their individual overall competitive indices. The use of a ratio, rather than the absolute magnitude of the difference of the indices, easily lends itself to a graphic explanation of the proposed allocation technique. This is accomplished by using

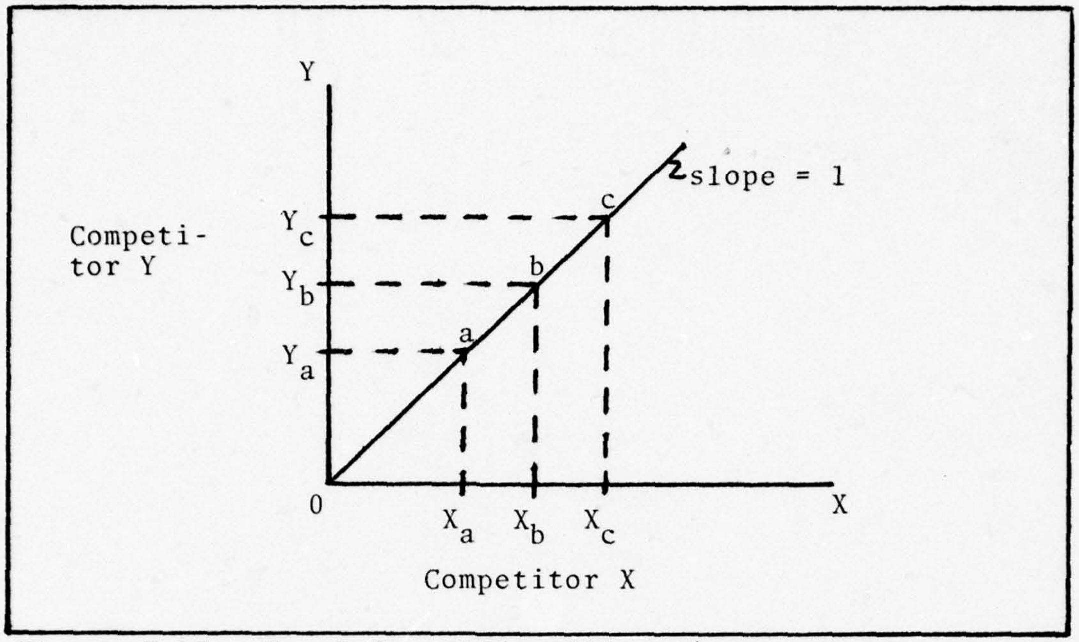



Figure 3.17. Equal Competitor Allocations

the slope of a line to represent the ratio of the overall competitive indices. Placing one end of this sloped line at the origin of an X-Y coordinate system, the X and Y coordinates of any point along the line could be used to determine the final allocations.

It was previously stated that if both competitiors were equal, then both should be awarded equal allocations. For purposes of the competitive procurement situation under consideration, the competitors are considered equal when the ratio of the overall competitive indices is represented by a line with a slope of one. In such a case, the X and Y coordinates of any point on the line would be equal and represent allocations of 50% for each of the competitors. Fig 3.17

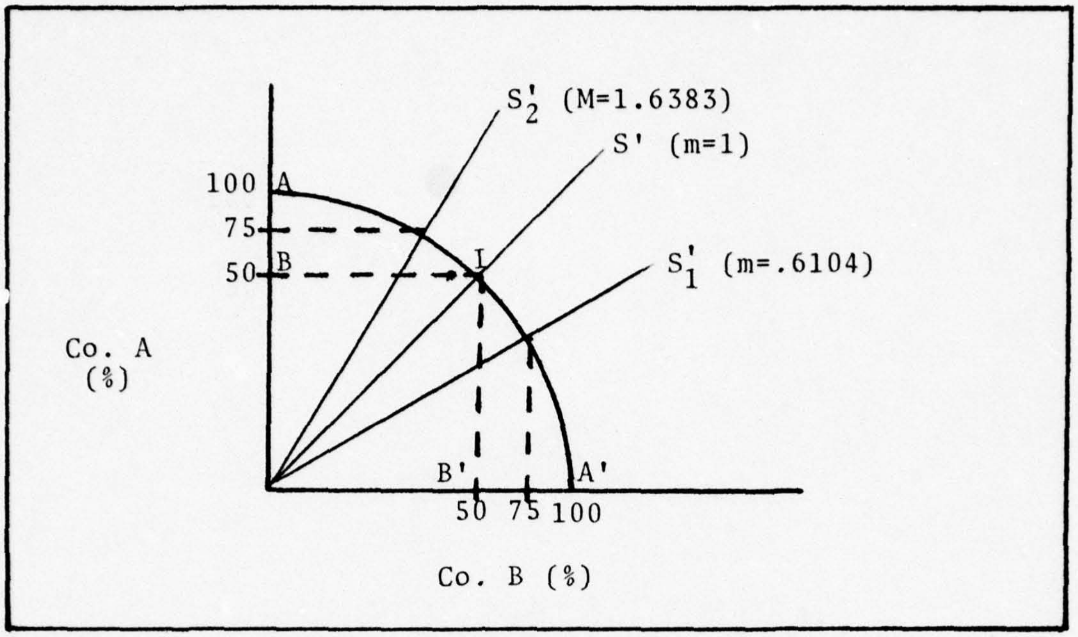


Figure 3.18. Variable Competitor Allocations

depicts this relationship. The diagonal line has a slope of one, and the points a, b, and c all have X and Y coordinates which are equal.

In order to determine the allocations when the slope is something other than one, an arc, of radius one and centered at the origin, is drawn on the X-Y coordinate system. The point of intersection (I) of the sloped line (OS') and the 90-degree arc (AA') is used to determine the allocations. See Fig. 3.18. Points on the X and Y axes correspond to the allocations awarded to the competitors. When the line OS' has a slope of one, the points B and B' both represent allocations of 50% of the total procurement. The points A and A' each represent an allocation of 100% for the corresponding competitor. The line segments AB and A'B' represent uniformly

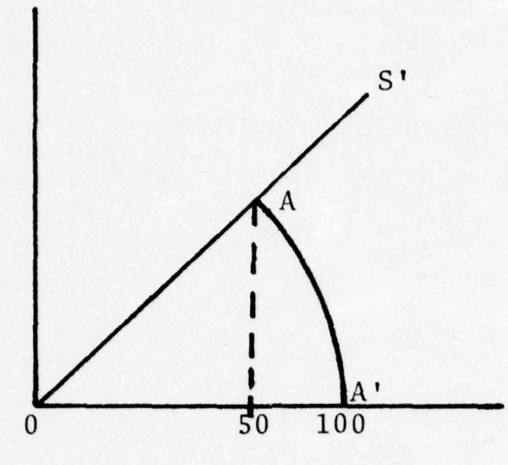



Figure 3.19. Low Index Competitor Allocation

distributed allocation levels. The line $OS_1'$, with slope 0.6104, corresponds to a 75% allocation for Company B--its horizontal intercept is midway between B' (50%) and A' (100%). Company A's allocation would therefore be 25% (100% - 75% awarded to Co. B). The reverse would happen if the slope were the inverse of 0.6104. Line $OS_2'$, with slope 1.6383, corresponds to a 75% allocation for Company A and 25% for Company B.

Because of the symmetry about line OS', Fig. 3.18 can be simplified to Fig. 3.19 without altering the results. However, in this case, the slope of the line from the origin is always determined by dividing the lower of the two overall competitive indices by the higher index.

In order to increase the elasticity, or responsiveness of changes in allocations to changes in the index ratio

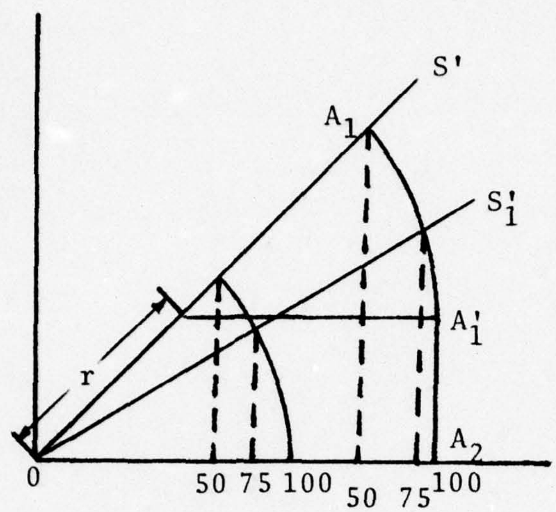



Figure 3.20. Changing Allocation Elasticity

(slope), a simple modification is made to Fig. 3.19. See Fig. 3.20. This modification is to move the origin of the arc AA' from point 0 to a point farther out the line OS'. A vertical line is added from point $A_1'$ to point $A_2$ to cover those cases in which the sloped line OS' would be below the arc. The farther the arc $A_1A_1'$ is moved the greater the elasticity.

With the origin of the arc located a distance of one unit from the original X-Y origin, the previous competitive index ratio of 0.6104 corresponds to a 91.82% allocation for the competitor having the lower index. This allocation is 1.22 times as large as it was for the same ratio before the arc was moved.

Table X

Allocations for Low Index Competitor

| Index Ratio (Slope) | Allocations * r=0 | r=1 | r=2 | r=3 |
|---|---|---|---|---|
| 1.00 | 50.00 | 50.00 | 50.00 | 50.00 |
| 0.90 | 56.18 | 62.00 | 67.48 | 72.60 |
| 0.80 | 62.59 | 73.55 | 82.85 | 90.39 |
| 0.70 | 69.14 | 84.03 | 94.45 | 99.67 |
| 0.60 | 75.67 | 92.60 | 99.90 | 100.00 |
| 0.50 | 81.98 | 98.28 | 100.00 | 100.00 |

*Allocations are given as % of total annual procurement.

Table X demonstrates the changes in the allocation levels for the low index competitor when the arc is moved different distances from the origin 0. The distance that the center of the arc has been moved from the origin is designated r in Fig. 3.20.

The line $A_1A_2$, which includes arc $A_1A_1'$, approximates the shape of the bottom half of the demand curve in Fig. 3.6. The most notable difference is that the maximum allocation in Fig. 3.6 is ($Q_t$ - MAR), or the total annual procurement minus an MAR allocation. However, the maximum allocation in Figs. 3.18 through 3.20 is 100%.

The MAR allocation requirement is handled easily in the proposed allocation technique by including one more minor modification. Using the variable elasticity method depicted

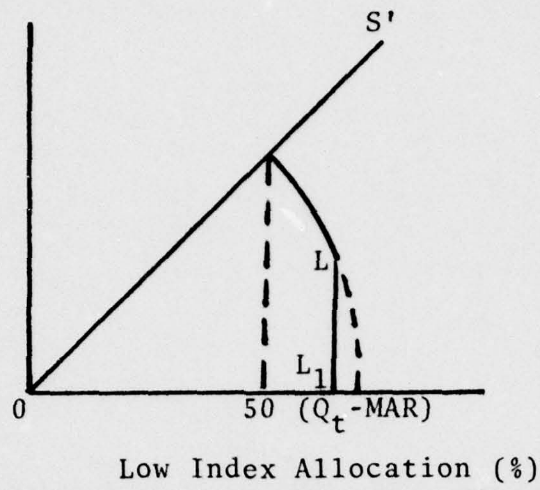



Figure 3.21. MAR Restriction Allocation

in Fig 3.20, a vertical line is drawn from the horizontal axis to the arc at the ($Q_t$ - MAR) allocation level. See Fig. 3.21. The line $LL_1$ limits the allocation for the low index competitor in such a way as to insure that the high index competitor will receive at least the MAR allocation.

A demonstration of the use of the entire proposed allocation technique is given in the following chapter.

# IV. DEMONSTRATION AND TESTING OF PROPOSED TECHNIQUE

## Introduction

The first part of this chapter employs hypothetical data to demonstrate the use of the proposed allocation technique. The same method is used for both competitors to determine the annual and overall competitive indices. Therefore, a complete demonstration of the computation of these indices is performed for only one competitor. This demonstration will include additional competitive factors, as discussed in Chapter II, and will use Method II to compensate for the difference in production experience, as discussed in Chapter III. Because of the inclusion of additional competitive factors, the Price Bids for each year, in Equations (4) and (5), are replaced by the annual competitive indices for the same years.

For testing, the most important criterion is whether or not the proposed technique reduces the overall procurement cost to the Government. There is no way to directly test the proposed technique with regard to this particular criterium. The hypothetical unit line price bids which will be used to test the proposed technique cannot be used to determine the Government cost under the SPO MAR allocation technique. This is due to the fact that the proposed technique is intended to reduce overall procurement costs by encouraging the competitors to reduce their prices at a rate faster than what would be expected under the SPO MAR allocation technique. However,

the proposed technique can be indirectly tested by determining how much the competitors' prices would have to be decreased under the MAR technique in order to equal the total procurement cost with the proposed technique.

Testing and evaluation of the proposed technique, as performed in this chapter, demonstrate: a) whether or not rapid price reductions are encouraged; b) the degree to which competitive performance is rewarded, and; c) whether or not the technique can prevent gaming by the competitors. Separate, but similar, tests are conducted for both the low index bidder and the high index bidder.

## Demonstration of the Proposed Allocation Technique

This demonstration is based on a hypothetical procurement which includes four additional competitive factors, as well as the unit line price bids, for the two-contractor competition. The data given in Table XI is used to demonstrate the computation of the annual and overall competitive indices for either competitor. Following these computations, a demonstration is given using the ratio of the overall competitive indices to determine the allocations awarded to the competitors.

Computation of Competitive Indices. The following five steps use the data from Table XI to determine the annual and overall competitive indices:

1. Use Equation (1) to determine the index value for each additional competitive factor.

Table XI

Data for Indices Computations

MAR: 20% of annual procurement quantity
Total Annual Procurement: 100,000 units
Additional Competitive Factors:

| Factor | Standard | Weight | $F_x$ |
|---|---|---|---|
| Reliability | 98% | .25 | $F_1$ |
| Velocity | 3,000 ft/min | .15 | $F_2$ |
| % on-time deliveries | 99% | .10 | $F_3$ |
| Degree of contractor cost risk | 100% | .40 | $F_4$ |

Contractor's Competitive Data:

| Factor | Rating |
|---|---|
| Reliability | 99% |
| Velocity | 3,200 ft/min |
| % on-time deliveries | 100% |
| Degree of cost risk | 100% (firm fixed price contract) |

Unit Line Price Bids at Five Allocation Levels:

| Allocation Level | Price per Unit |
|---|---|
| 20% (MAR) | $20.00 |
| 35% | $18.00 |
| 50% | $17.50 |
| 65% | $17.00 |
| 80% (100%-MAR) | $18.00 |

Annual Competitive Index for Year Prior: 18.75

Annual Competitive Index for Second Year Prior: 22.30

2. Using quadratic regression, fit a curve to the price bids of the competitors.

3. Determine the average unit price bids for both

competitors.

4. Use Equation (2), with the results obtained in steps 1 and 3, to determine the annual competitive indices for the current year.

5. Use Equation (4), with annual competitive indices substituted for Price Bids, to determine the competitor's overall competitive index for the current year.

Step 1 computes the additional competitive factor index values as follows:

$$F_x = \left[ 1 + \left( w_x \left( 1.00 - \frac{r_x}{s_x} \right) \right) \right] \qquad (1)$$

Therefore

$$F_1 = \left[ 1 + \left( .25 \left( 1.00 - \frac{.99}{.98} \right) \right) \right] = .9974$$

$$F_2 = \left[ 1 + \left( .15 \left( 1.00 - \frac{3200}{3000} \right) \right) \right] = .9900$$

$$F_3 = \left[ 1 + \left( .10 \left( 1.00 - \frac{1.00}{.99} \right) \right) \right] = .9990$$

$$F_4 = \left[ 1 + \left( .40 \left( 1.00 - \frac{1.00}{1.00} \right) \right) \right] = 1.0000$$

Step 2 results in a curve defined by the following:

$$y(x) = 19.0476x^2 - 22.3810x + 23.6714$$

where $\underline{y}$ is the unit line price bid as a function of $\underline{x}$, the

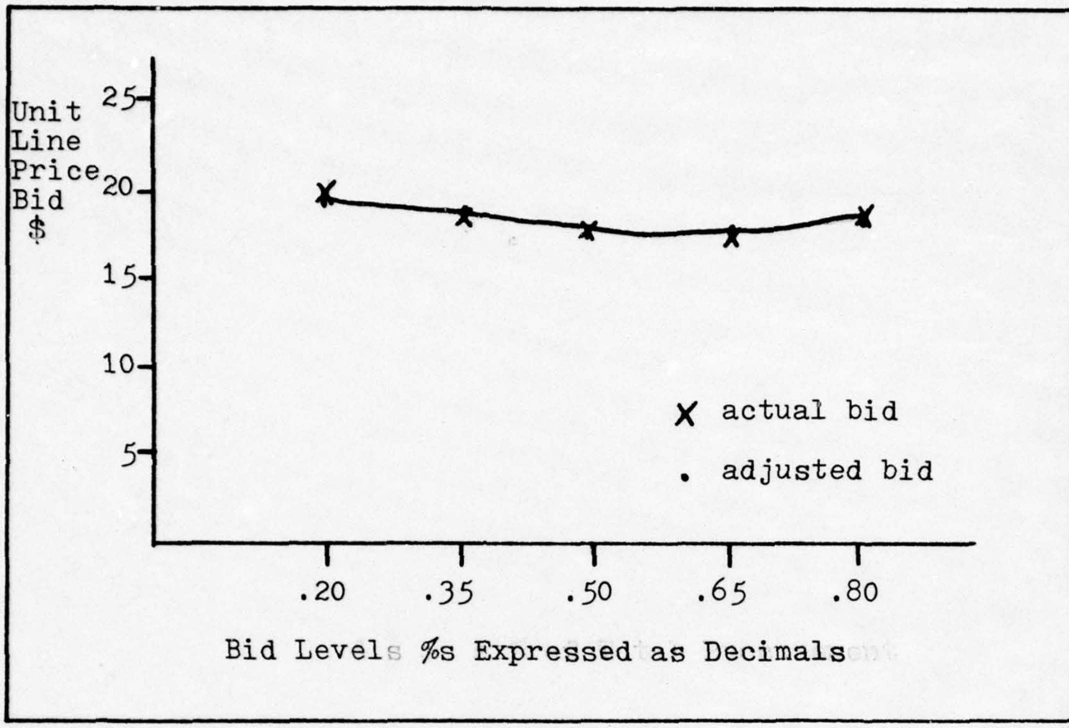



Figure 4.1. Demonstration of Bid Adjustment

percent allocation awarded (expressed as a decimal). See Figure 4.1.

Step 3 integrates the function in step 2 over the interval from $\underline{x}$ equals .20 (20%) to $\underline{x}$ equals .80 (100% - MAR). Dividing this quantity by .60, the length of the interval, gives an average unit line price bid of $17.81.

Step 4 computes the annual competitive index as follows:

$$I_c = (P_c)(F_1)(F_2)(F_3)(F_4) \qquad (2)$$

where $P_c$ is the average unit line price bid, and $F_1$ through $F_4$ are the values computed in step 1. Therefore, the annual

competitive index is

$$I_c = (17.81)(.9974)(.9900)(.9990)(1.0000) = 17.57$$

Step 5 computes the overall competitive index for the current year as follows:

$$\text{Overall Competitive Index}_n = \text{Annual Index}_n \times \frac{\text{Annual Index}_n}{\text{Annual Index}_{n-1}} \times \frac{\text{Annual Index}_{n-1}}{\text{Annual Index}_{n-2}} \quad (4)$$

where overall and annual indices have been substituted for the price bids of the original equation because of the inclusion of additional competitive factors, and $n$ is the current year. Therefore, the Overall Competitive Index for this year is

$$17.57 \times \frac{17.57}{18.75} \times \frac{18.75}{22.30} = 13.84$$

After completion of these same five steps for the other competitor, the Overall Competitive Indices for both competitors are used with the proposed allocation technique to determine the respective allocations for the current year procurement. For demonstration purposes, it will be assumed that this 13.84 is the Overall Competitive Index for Company A, and that 15.50 is the index for Company B.

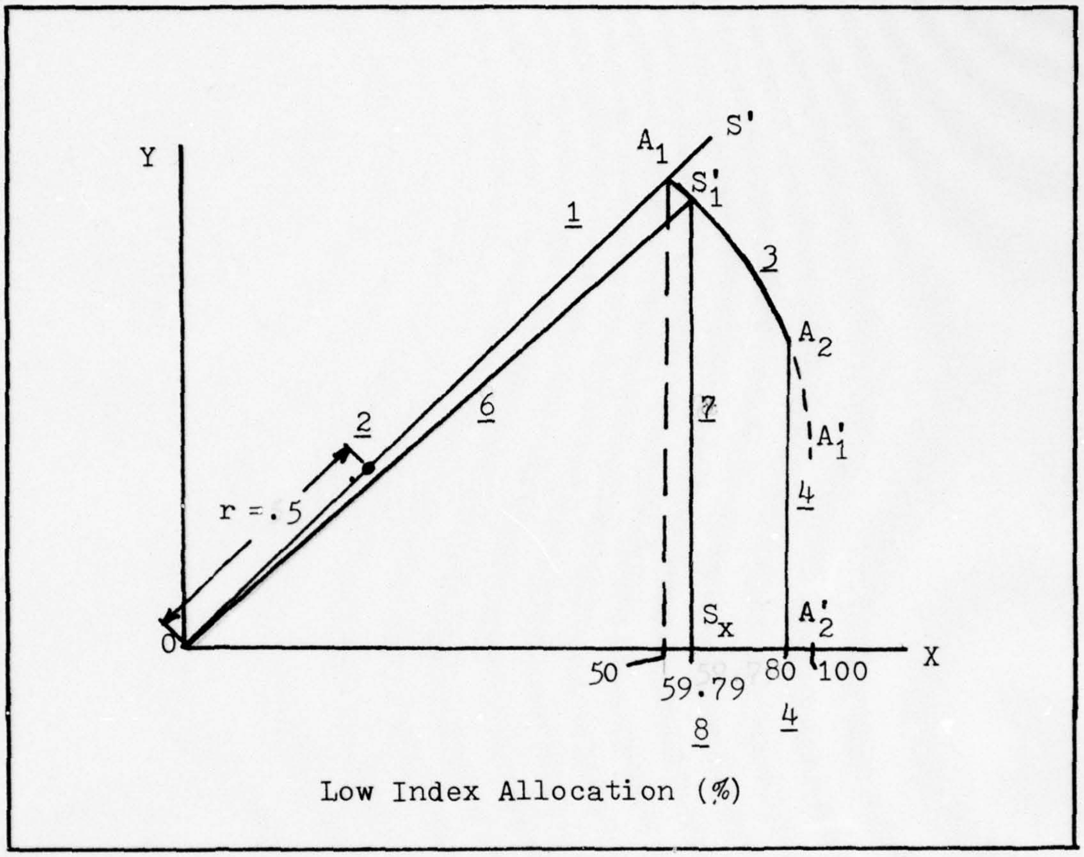



Figure 4.2. Graphic Determination of Low Index Allocation

Determination of Allocations. The allocations awarded to each of the competitors are determined by using the proposed allocation technique as illustrated in Figures 3.20 and 3.21 and described in Table X. The underlined numbers in Figure 4.2 correspond to the following eight steps which are used to determine the allocations.

Step 1. On an X-Y coordinate system plot a line with a slope of one extending from the origin. This line is labelled OS' in Figure 4.2.

Step 2. If an increased degree of elasticity is to be

AD-A069 908 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCH--ETC F/G 5/1
PROPOSED ALLOCATION TECHNIQUE FOR A TWO-CONTRACTOR PROCUREMENT.(U)
MAY 79 J L PELZER

UNCLASSIFIED AFIT/GSM/SM/77D-26 NL

2 OF 2
AD
A069908

END
DATE
FILMED
7-79
DDC

used, as explained in Chapter III, determine the distance r, along the line OS', which the origin of the allocation arc is to be moved. In Figure 4.2, r has a length of .5 units.

Step 3. Plot, down from line OS', a 45-degree allocation arc ($A_1A_1'$) with a radius of 1.0 units.

Step 4. Locate on the X axis the 50% and 100% allocation levels. As explained in Chapter III, allocations between these levels are uniformly distributed. If the procurement has an MAR restriction, as is the case here, plot a vertical line ($A_2A_2'$) from the X axis to the allocation arc ($A_1A_1'$) at the (100% - MAR) allocation level. In Figure 4.2 the (100% - MAR) level is at 80%. The new allocation line ($A_1A_2A_2'$) replaces the allocation arc for determining the final allocations to be awarded.

Step 5. Determine the ratio of the lower Overall Competitive Index to the higher one. From the previous section of this chapter, the ratio of Company A's index, 13.84, to Company B's, 15.50, is .89.

Step 6. Plot a line, with a slope equal to the ratio found in step 5, from the X-Y origin to the allocation line ($A_1A_2A_2'$). The point of intersection of these lines is labelled $S_1'$.

Step 7. Plot a vertical line ($S_1'S_x$) from point $S_1'$ down to the X axis.

Step 8. The allocation to be awarded to the competitor with the lower Overall Competitive Index is read at point $S_x$.

With the data used for this demonstration, Company A would be awarded an allocation of 59.79% of the total annual procurement. The remaining 40.21% would be awarded to Company B. The dollar amounts of the two contracts would then be determined by use of the fitted curve derived in step 2 of the Computation of Competitive Indices section. For Company A the price per unit would be

$$19.0476(.5979)^2 - 22.3810(.5979) + 23.6714 = \$17.0990$$

The total price of the contract with Company A would then be

$$100{,}000 \text{ units } X .5979 \text{ X } \frac{\$17.0990}{\text{unit}} = \$1{,}022{,}349.21$$

This same procedure would be followed, using a fitted curve for Company B's unit line price bids, to determine the total price of the contract with Company B for the remaining 40.21% of the annual procurement.

## Testing of the Proposed Allocation Technique

The testing of the proposed allocation technique is accomplished with the use of hypothetical data for both competitors. The testing covers a four-year period during which changes in contractor allocations are evaluated under various combinations of unit line price bid patterns. The first series of tests evaluate the allocations awarded to

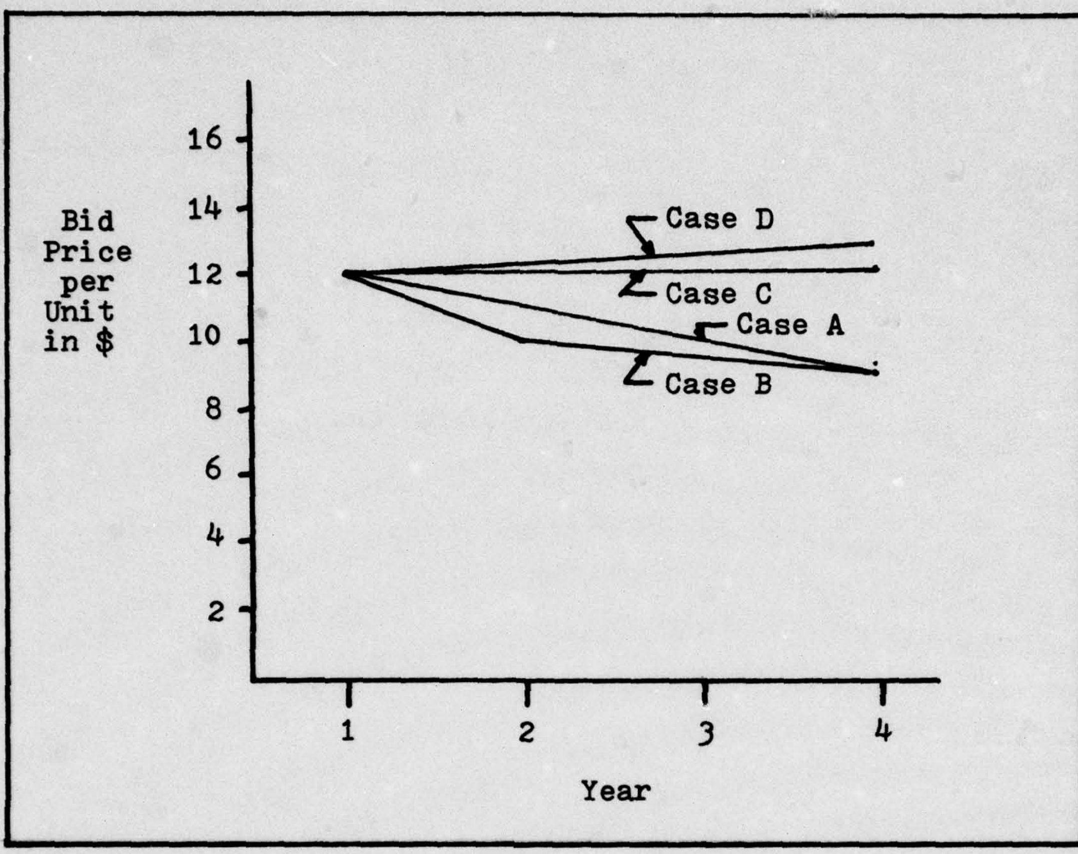



Figure 4.3. Bid Patterns for Testing Proposed Technique

the low index competitor, Company A, under various price bid patterns while the price bids of the high index competitor, Company B, gradually decrease over the four-year period. The price bid patterns for Company A are listed as: Case A, a continuous gradual decrease in bid price; Case B, a large initial decrease followed by a very slight decrease; Case C, a constant bid price; and, Case D, a continuous gradual increase. These price bid patterns are illustrated in Figure 4.3. The second series of tests evaluate the allocations awarded to Company B when the pricing patterns for the two

Table XII

Test Data for Low Index Competitor

MAR: 20% of annual procurement
Total Annual Procurement: 1,000,000 units
Additional Competitive Factors: NONE
4-Year Price Bid Patterns (in dollars per unit):

| | Yr 1 | Yr 2 | Yr 3 | Yr 4 |
|---|---|---|---|---|
| Case A. Gradual decrease | 12.00 | 11.00 | 10.00 | 9.00 |
| Case B. Rapid initial decrease | 12.00 | 10.00 | 9.50 | 9.00 |
| Case C. Constant price bid | 12.00 | 12.00 | 12.00 | 12.00 |
| Case D. Gradual increase | 12.00 | 12.25 | 12.50 | 12.75 |
| High Index Competitor Price Bid Pattern:* | 16.00 | 15.00 | 14.00 | 13.00 |

* This pattern is the same for all four test cases.

competitors are reversed.

The purpose of these two series of tests is to determine whether or not the proposed allocation technique results in allocations which both reflect the relative competitive performance of the two contractors and encourage rapid price reductions.

Low Index Competitor Tests. The data used for testing the proposed allocation technique with regard to the low index competitor are listed in Table XII. No additional competitive factors are included in the test scenarios. The unit line price bids are therefore the sole basis for deciding

the competitive allocations.

In order to facilitate the computation of test results, one assumption is made concerning the annual unit line price bids. This assumption is that the annual unit line price bids are constant over the entire range of allocations which could be awarded to either contractor in any given year. Because of this assumption and the absence of additional competitive factors, the annual unit line price bids become the annual competitive indices.

Testing the proposed allocation technique for Cases A, B, C, and D of Table XII gives the results which are summarized in Table XIII. Examination of these results reveals that those cases in which the unit line price bids decreased, Cases A and B, resulted in greater contractor total revenue for Company A than did the cases in which the bids either remained constant or increased, Cases C and D. For Cases A and B, the greater contractor total revenue resulted when the major portion of the unit price bid reduction occurred in the earlier years, Case B. The use of present value analysis shows the results of Case B to be even more favorable. For Cases C and D, the lesser contractor total revenue resulted when the unit price bids increased as opposed to remaining constant.

In terms of the purpose of these tests, the proposed allocation technique does encourage rapid price reductions. Cases A and B both reduced prices the same amount over the

Table XIII

Low Index Test Results

**Case A**

| | Yr 1* | Yr 2 | Yr 3 | Yr 4 |
|---|---|---|---|---|
| Company A | | | | |
| Overall Index | 12.000 | 9.243 | 8.333 | 7.364 |
| Allocation % | 65.86 | 69.07 | 70.44 | 72.19 |
| Revenue in $ | 7,902,944 | 7,597,721 | 7,044,000 | 6,497,100 |
| Present Value** | | 6,907,019 | 5,821,488 | 4,881,367 |
| Total Revenue Yrs 2-4 | | | | $21,138,821 |
| Present Value** | | | | $17,609,874 |
| Company B | | | | |
| Overall Index | 16.000 | 13.184 | 12.250 | 11.267 |
| Allocation % | 34.14 | 30.93 | 29.56 | 27.81 |
| Revenue | 7,462,742 | 4,639,471 | 4,138,400 | 3,615,300 |
| Present Value | | 4,217,700 | 3,420,165 | 2,716,228 |
| Total Revenue Yrs 2-4 | | | | $12,393,171 |
| Present Value | | | | $10,354,095 |
| Government | | | | |
| Total Cost of Procurement Yrs 2-4 | | | | $33,351,992 |
| Present Value | | | | $27,963,969 |

**Case B**

| | Yr 1* | Yr 2 | Yr 3 | Yr 4 |
|---|---|---|---|---|
| Company A | | | | |
| Overall Index | 12.000 | 6.944 | 7.521 | 8.100 |
| Allocation % | 65.86 | 80.00 | 74.77 | 67.90 |
| Revenue | 7,902,944 | 8,000,000 | 7,103,150 | 6,111,000 |
| Present Value | | 7,272,727 | 5,870,372 | 4,591,294 |
| Total Revenue Yrs 2-4 | | | | $21,214,150 |
| Present Value | | | | $17,734,383 |
| Company B | | | | |
| Overall Index | 16.000 | 13.184 | 12.250 | 11.267 |
| Allocation % | 34.14 | 20.00 | 25.23 | 32.10 |
| Revenue | 5,462,742 | 3,000,000 | 3,532,200 | 4,173,000 |
| Present Value | | 2,727,272 | 2,919,173 | 3,135,237 |
| Total Revenue Yrs 2-4 | | | | $10,705,200 |
| Present Value | | | | $8,781,682 |
| Government | | | | |
| Total Cost of Procurement Yrs 2-4 | | | | $31,919,350 |
| Present Value | | | | $26,516,065 |

Table XIII continued

| Case C | Yr 1* | Yr 2 | Yr 3 | Yr 4 |
|---|---|---|---|---|
| Company A | | | | |
| Overall Index | 12.000 | 12.000 | 12.000 | 12.000 |
| Allocation % | 65.86 | 55.54 | 51.24 | 46.26 |
| Revenue | 7,902,944 | 6,664,800 | 6,148,800 | 5,551,200 |
| Present Value** | | 6,058,909 | 5,081,652 | 4,170,698 |
| Total Revenue Yrs 2-4 | | | | $18,364,800 |
| Present Value | | | | $15,311,261 |
| Company B | | | | |
| Overall Index | 16.000 | 13.184 | 12.250 | 11.267 |
| Allocation % | 34.14 | 44.46 | 48.76 | 53.74 |
| Revenue | 5,462,742 | 6,669,000 | 6,826,400 | 6,986,200 |
| Present Value | | 6,062,727 | 5,641,653 | 5,248,835 |
| Total Revenue Yrs 2-4 | | | | $20,481,600 |
| Present Value | | | | $16,953,215 |
| Government | | | | |
| Total Cost of Procurement Yrs 2-4 | | | | $38,846,400 |
| Present Value | | | | $32,264,476 |
| Case D | | | | |
| Company A | | | | |
| Overall Index | 12.000 | 12.766 | 13.021 | 13.270 |
| Allocation % | 65.86 | 51.93 | 46.37 | 40.58 |
| Revenue | 7,902,944 | 6,361,425 | 5,796,250 | 5,173,950 |
| Present Value | | 5,783,114 | 4,790,289 | 3,887,265 |
| Total Revenue Yrs 2-4 | | | | $17,331,625 |
| Present Value | | | | $14,460,668 |
| Company B | | | | |
| Overall Index | 16.000 | 13.184 | 12.250 | 11.267 |
| Allocation % | 34.14 | 48.07 | 53.63 | 59.42 |
| Revenue | 5,462,742 | 7,210,500 | 5,508,200 | 7,724,600 |
| Present Value | | 6,555,000 | 6,205,124 | 5,803,606 |
| Total Revenue Yrs 2-4 | | | | $22,443,300 |
| Present Value | | | | $18,563,730 |
| Government | | | | |
| Total Cost of Yrs 2-4 | | | | $39,774,925 |
| Present Value | | | | $33,024,398 |

*Results for Yr 1 are not used for evaluation. Data calculated ising annual index as overall index. As stated in this report, first year allocations should be made using any method procuring agency deems appropriate.
**Present Value at start of Yr 2. Discount factor is 10%.

four-year period. But the more rapid reduction in the initial years of Case B resulted in the greater total revenue being received by Company A. Using both the amount of reduction and the rate at which the reduction occurs as measures of competitive performance, the bid price pattern of Case B would have to be considered the most competitive. Cases A, C, and D, in that order, would then show decreasing degrees of competitive performance. The allocations awarded, the contractor total revenue received, and the total costs to the Government all reflect this decreasing order of competitive performance.

The following observations can be made regarding the ability of the proposed allocation technique to reduce the overall procurement costs to the Government as compared to the SPO MAR allocation technique. First of all, the results shown for Year 1 in Table XIII should be disregarded. This is due to the fact that the procuring agency may use any allocation technique which is considered appropriate - including the SPO technique - for the first year allocations. Therefore, the cost reductions must be measured during the period of Years 2 through 4. Using the SPO technique, and the starting prices of $12.00 and $16.00 per unit, each annual procurement would cost $12,800,000. This is based on buying 80% (100% - MAR) from the low bidder and 20% (MAR) from the high bidder. This is an average of $12.80 per unit. In order to purchase the 3 million units for Years 2 through

Table XIV

Test Data for High Index Competitor

MAR: 20% of annual procurement
Total Annual Procurement: 1,000,000 units
Additional Competitive Factors: NONE
4-Year Price Bid Patterns (in dollars per unit):

| | Yr 1 | Yr 2 | Yr 3 | Yr 4 |
|---|---|---|---|---|
| Case E. | Gradual decrease | | | |
| | 16.00 | 15.00 | 14.00 | 13.00 |
| Case F. | Rapid initial decrease | | | |
| | 16.00 | 14.00 | 13.50 | 13.00 |
| Case G. | Constant price bid | | | |
| | 16.00 | 16.00 | 16.00 | 16.00 |
| Case H. | Gradual increase | | | |
| | 16.00 | 16.25 | 16.50 | 16.75 |
| Low Index Competitor Price Bid Pattern:* | | | | |
| | 12.00 | 11.00 | 10.00 | 9.00 |

* This pattern is the same for all four test cases.

4 at the Case B total cost of $31,919,350, the average price would have to decrease to $10.64 per unit.

A similar series of tests for the high index competitor will be used to verify these results.

High Index Competitor Tests. Testing of the proposed allocation technique with regard to the performance of the high index competitor, Company B, is conducted in the same manner as for the low index competitor. And, as in the low index competitor tests, there are no additional competitive factors and the annual unit line price bids are assumed to

be constant over the entire range of allocation levels. The same basic price bid patterns are repeated for Company B, but at higher price bid levels than for Company A. The data used for testing the proposed allocation technique with regard to the high index competitor are listed in Table XIV. The price bid patterns for Cases E, F, G, and H are in the same order as for Cases A, B, C, and D of the low index competitor tests.

The results of testing Cases E through H for the high index competitor are summarized in Table XV. These results are very similar to those obtained in the low index competitor tests. As in the previous tests, those cases in which the unit line price bids decreased, Cases E and F, resulted in greater total contract revenue for the competitor being tested. And the greatest contractor total revenue resulted when the major portion of the unit price bid reduction was in the initial years of the competition. However, for the high index competitor there is one difference in the test results.

Company B receives a slightly greater contractor total revenue in Case H (gradually rising price bids) than in Case G (constant price bids). The hypothetical data used for these cases resulted in a total contractor revenue which was 0.33% greater for Case H than for Case G. Comparison of the present value totals, however, shows the total contractor revenue was almost identical. The explanation for this

Table XV

High Index Test Results

| | Yr 1* | Yr 2 | Yr 3 | Yr 4 |
|---|---|---|---|---|
| **Case E** | | | | |
| Company B | | | | |
| Overall Index | 16.000 | 13.184 | 12.250 | 11.267 |
| Allocation % | 34.14 | 30.93 | 29.56 | 27.81 |
| Revenue in $ | 5,462,742 | 4,639,471 | 4,138,400 | 3,615,300 |
| Present Value** | | 4,217,700 | 3,420,165 | 2,716,228 |
| Total Revenue Yrs 2-4 | | | | $12,393,171 |
| Present Value** | | | | $10,354,095 |
| Company A | | | | |
| Overall Index | 12.000 | 9.243 | 8.333 | 7.364 |
| Allocation % | 65.86 | 69.07 | 70.44 | 72.19 |
| Revenue in $ | 7,902,944 | 7,597,721 | 7,044,000 | 6,497,100 |
| Present Value | | 6,907,019 | 5,821,488 | 4,881,367 |
| Total Revenue Yrs 2-4 | | | | $21,138,821 |
| Present Value | | | | $17,609,874 |
| Government | | | | |
| Total Cost of Procurement Yrs 2-4 | | | | $33,351,992 |
| Present Value | | | | $27,963,969 |
| **Case F** | | | | |
| Company B | | | | |
| Overall Index | 16.000 | 10.719 | 11.391 | 12.071 |
| Allocation % | 34.14 | 41.43 | 32.93 | 24.98 |
| Revenue | 5,462,742 | 5,800,200 | 4,445,500 | 3,247,400 |
| Present Value | | 5,272,909 | 3,674,008 | 2,439,820 |
| Total Revenue Yrs 2-4 | | | | $13,493,100 |
| Present Value | | | | $11,386,737 |
| Company A | | | | |
| Overall Index | 12.000 | 9.243 | 8.333 | 7.364 |
| Allocation % | 65.86 | 58.57 | 67.07 | 75.02 |
| Revenue | 7,902,944 | 6,442,700 | 6,707,000 | 6,751,800 |
| Present Value | | 5,857,000 | 5,542,975 | 5,072,727 |
| Total Revenue Yrs 2-4 | | | | $19,901,500 |
| Present Value | | | | $16,472,702 |
| Government | | | | |
| Total Cost of Procurement Yrs 2-4 | | | | $33,394,600 |
| Present Value | | | | $27,859,439 |

Table XV continued

| Case G | Yr 1 | Yr 2 | Yr 3 | Yr 4 |
|---|---|---|---|---|
| Company B | | | | |
| Overall Index | 16.000 | 16.000 | 16.000 | 16.000 |
| Allocation % | 34.14 | 22.89 | 20.00 | 20.00 |
| Revenue | 5,462,742 | 3,662,400 | 3,200,000 | 3,200,000 |
| Present Value | | 3,329,455 | 2,644,628 | 2,404,207 |
| Total Revenue Yrs 2-4 | | | | $10,062,400 |
| Present Value | | | | $8,378,290 |
| Company A | | | | |
| Overall Index | 12.000 | 9.243 | 8.333 | 7.364 |
| Allocation % | 65.86 | 77.11 | 80.00 | 80.00 |
| Revenue | 7,902,944 | 8,482,100 | 8,000,000 | 7,200,000 |
| Present Value | | 7,711,000 | 6,611,570 | 5,409,467 |
| Total Revenue Yrs 2-4 | | | | $23,682,100 |
| Present Value | | | | $19,732,037 |
| Government | | | | |
| Total Cost of Procurement Yrs 2-4 | | | | $33,744,500 |
| Present Value | | | | $28,110,327 |
| Case H | | | | |
| Company B | | | | |
| Overall Index | 16.000 | 16.763 | 17.016 | 17.265 |
| Allocation % | 34.14 | 21.22 | 20.00 | 20.00 |
| Revenue | 5,462,742 | 3,448,250 | 3,300,000 | 3,350,000 |
| Present Value | | 3,134,773 | 2,727,273 | 2,516,905 |
| Total Revenue Yrs 2-4 | | | | $10,098,250 |
| Present Value | | | | $8,378,951 |
| Company A | | | | |
| Overall Index | 12.000 | 9.243 | 8.333 | 7.364 |
| Allocation % | 65.86 | 78.78 | 80.00 | 80.00 |
| Revenue | 7,902,944 | 8,665,800 | 8,000,000 | 7,200,000 |
| Present Value | | 7,878,000 | 6,611,570 | 5,409,467 |
| Total Revenue Yrs 2-4 | | | | $23,865,800 |
| Present Value | | | | $19,899,037 |
| Government | | | | |
| Total Cost of Procurement Yrs 2-4 | | | | $33,964,050 |
| Present Value | | | | $28,277,988 |

*Results for Yr 1 are not used for evaluation. See footnotes at end of Table XIII.

**Present Value at start of Yr 2. Discount factor is 10%.

reversal from the low index competitor case follows.

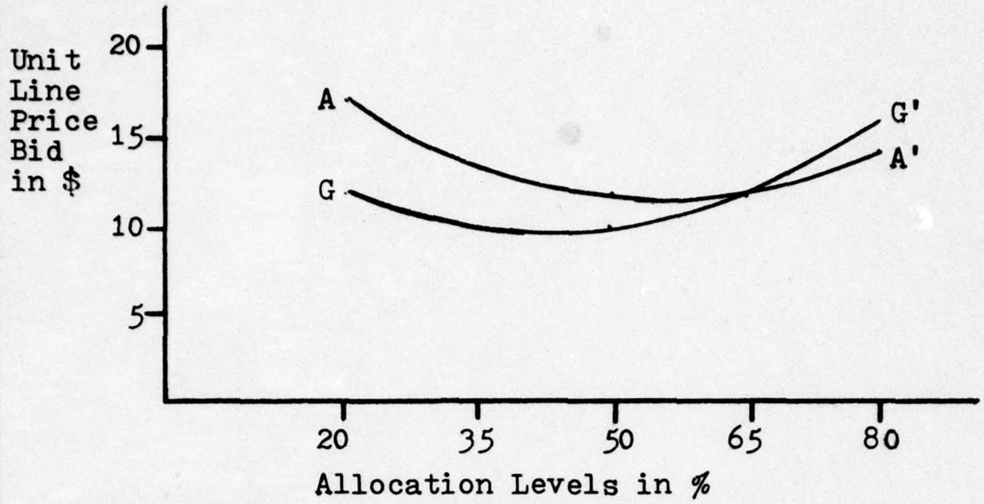
In both cases, G and H, Company B was protected by the MAR restriction of a 20% minimum allocation. This restriction is imposed by either the SPO or the procuring agency and is not an inherent part of the proposed allocation technique. Had the MAR restriction not been included, the Company B allocations for Case G would have been 19.30% in Year 3 and 15.64% in Year 4. For Case H the allocations would have been only 17.40% and 13.69% respectively. Using these allocations, Case G would have given Company B a total contractor revenue of $9,252,800, present value $7,761,611, whereas Case H would have given only $8,612,325, present value $7,230,321.

The proposed allocation technique, without the MAR restriction, again is shown to provide allocations which encourage rapid price reductions and which reflect the competitive performance of the competitors. The competitive performance is also reflected in the contractor total revenue and the overall procurement costs to the Government.

Another example of how the proposed allocation technique reflects the competitive performance of the two contractors is demonstrated by the changes in allocations in Cases A and E. Both of these cases, incidentally, use the same data. In these cases both competitors reduce their unit price bids by one dollar per year. However, in each successive year Company A is awarded an increased allocation. This

reflects the more competitive performance of Company A in that the annual one dollar reduction is a larger percentage of the Company A price than it is of the Company B price.

Gaming and the Proposed Allocation Technique. This final section on testing of the proposed allocation technique examines three different methods which may be used by the competitors in attempting to "game" the technique as presented. The means to deter these attempts are also examined. For the purposes of this section, gaming refers to a competitor playing some strategy which will gain for him the advantages of a level of competitive performance which exceeds the level at which he actually performs. The level of competitive performance, for the most part, is measured in terms of unit line price bids. The more a competitor's price bids decrease, measured in both magnitude and percentage, and the more rapid the decrease, the higher the level of competitive performance is assumed to be. However, a strategy may be used in which the price bids seem to decrease while the purchase price actually increases due to the allocation level awarded. This strategy will be the first gaming method examined in this section. The second way a competitor may attempt to game the technique is by increasing the profit margin at a rate which exceeds that of any cost decrease. Though the net effect of such a strategy might be a reduction in the overall procurement cost to the Government, excessive profit rates would indicate that further reductions are possible. The final means




Unit Bids by Allocation Level

| | 20% | 35% | 50% | 65% | 80% | Avg |
|---|---|---|---|---|---|---|
| Actual* | 17.00 | 13.00 | 12.00 | 12.00 | 14.00 | 12.98 |
| Gamed** | 12.00 | 10.00 | 10.00 | 12.00 | 16.00 | 11.33 |

* depicted as line AA'
** depicted as line GG'

Figure 4.4. Price Bid Gaming

of gaming the proposed allocation technique involves the high index competitor using MAR restrictions to protect high prices rather than to support his competitive position.

Price Bid Gaming. Either competitor could submit unit line price bids which improve his competitive position even though those bids actually increase his selling price. This gaming strategy is demonstrated using the data depicted in Figure 4.4. Whether or not a competitor would choose to employ this strategy is highly dependent

upon the degree of certainty with which he can predict the competitive performance of the other contractor.

In Figure 4.4 the line AA' represents the fitted curve for the unit line price bids which Company A would have submitted if no gaming were involved. The chart at the bottom of Figure 4.4 shows that the average unit price bid with line AA' is $12.98. However, after studying the operation of Company B, Company A determines that there is better than an 80% probability that Company A will be allocated at least 75% of the annual procurement if it submits an average bid of $11.33 per unit. Because Company A can do nothing to reduce the costs associated with the actual bids shown by line AA', the average unit price bid can be reduced only by gaming. Company A therefore submits the gamed bids which are shown by line GG'. The average price with these bids is the required $11.33. Looking only at the gamed bids (which is all the procuring agency would see), Company A appears to have performed much more competitively than the actual (AA') bids would have indicated.

Assume the determination by Company A was correct and an allocation of 75% is awarded. The units purchased from Company A will now cost more - even though the average price bid decreased! Using the ungamed price bids, an allocation of 75% would have cost $13.15 per unit. The cost of these same units, when the bids are gamed, is $14.44 per unit. Company A gains two ways from the gamed bids: a

larger allocation is awarded and a higher price per unit is received.

The proposed allocation technique provides only an indirect means of detering this type of gaming in that increasing the degree of elasticity used to determine the allocations may provide some degree of deterence. For example, in the situation just described, if Company B had submitted a bid which averaged $1.00 per unit less than whatever bid it submitted, Company A might have received an allocation of only 65%. This one-dollar error would have cost Company A nothing because the price using either of the depicted curves is $12.00 per unit at the 65% level. But, if the degree of elasticity used for the allocations had been greater, the $1.00 per unit decrease by Company B might have reduced the allocation for Company A to 55%. In this case, the gamed bids would have reduced the unit purchase price from the AA' price of $11.61 per unit to the GG' price of $10.44. Company A would have lost $1.17 per unit as compared to what the price would have been without gaming. Using an increased degree of elasticity, to increase the risk of this loss situation occurring , is the only deterent provided by the proposed allocation technique. The method used to increase the degree of elasticity is discussed in Chapter III.

This first gaming strategy gives the impression of greater than actual contractor cost reductions. The second

strategy gives the opposite impression by converting a portion of the contractor cost reductions to increased profits.

Conversion of Cost Reductions to Profit. The testing section of this chapter demonstrated how the proposed allocation technique reflects the competitive performance of the two contractors through allocation levels, total contractor prices, and overall procurement costs to the Government. The last item, overall procurement costs, covered the primary concern of the Government. But, even though it may well be the primary concern of the competitors, profit was not specifically addressed. It was only addressed indirectly to the extent that, as a constant percentage of either cost or contract price, profit would reflect competitive performance in the same manner. By changing profit rates, either competitor may receive profits which do not reflect the actual competitive performance. The gaming strategy discussed in this section is concerned with a competitor being able to split a reduction in production costs between price decreases and profit increases. In order to demonstrate this strategy, the results of test Case A are used. Table XVI gives a comparison of profit levels when Company A converts cost reductions to increased profits.

For the purpose of demonstrating this gaming strategy, Case A reflects the actual competitive price bidding of

Table XVI

Profit Comparisons When Gaming the Rate of Profit

| (Case A) | Yr 2 | Yr 3 | Yr 4 | Total |
|---|---|---|---|---|
| (I) Unit Line Price Bid | $11.00 | $10.00 | $9.00 | |
| Rate of Profit | 20.00% | 20.00% | 20.00% | |
| Cost Per Unit | $9.17 | $8.33 | $7.50 | |
| Profit Per Unit | $1.83 | $1.67 | $1.50 | |
| Annual Profit* | $1,267 | $1,174 | $1,083 | $3,524 |
| (II) Unit Line Price Bid | $11.17 | $10.33 | $9.50 | |
| Rate of Profit | 21.81% | 24.01% | 26.67% | |
| Cost Per Unit | $9.17 | $8.33 | $7.50 | |
| Profit Per Unit | $2.00 | $2.00 | $2.00 | |
| Annual Profit* | $1,338 | $1,349 | $1,360 | $4,047 |

* Annual Profit is given in $1,000's.

Company A. It is assumed that the $12.00 unit line price bid, used for Year 1 of Case A, includes $10.00 of production costs and $2.00 of profit. Therefore, the profit rate at the start of the competition period is equal to 20.00% of the cost per unit. In Table XVI, Case A (I) shows the costs and profits per unit, as well as the annual and total profits, when the unit line prices include a constant 20.00% profit rate. Because the rate of profit is held constant, the annual unit price decreases include reductions in both unit costs and unit profit. For Case A (I) the total profit for Years 2 through 4 is $3,523,842.

Case A (II) illustrates the increased profits which would result if the annual unit line price bids were to be

gamed using a strategy which converts a portion of the decreased costs to increased profits. Comparison of the annual unit costs for Cases A (I) and A (II), in Table XI, shows that they are the same. However, in Case A (II) Company A maintains a constant $2.00 per unit profit by converting 20.00% of the cummulative annual unit cost decreases to profit increases. This strategy raises the rate of profit from 20.00% of cost in Year 1 to 26.67% of cost in Year 4. And, even though the higher unit prices for Case A (II) resulted in slightly lower allocations each year, the increased rates of profit raise the total profit to $4,047,200. If the procuring agency were to assume that the competitors charge a constant rate of profit from one year to the next, then the unit line price bids for Case A (II) would give the impression that the cost reductions for Company A were less in the gamed case, Case A (II), than in the actual case, Case A (I).

The proposed allocation technique provides a very definite means of detering this type of gaming. This means is to include the rate of profit as an additional competitive factor, as explained in Chapter II, in determining the annual competitive indices for the two contractors. Because a rate of profit which exceeds the established standards has a negative value when compared to a decrease in the unit line price, the weight assigned to this additional competitive factor, $\underline{w}_x$ in Equation (1), would be a negative number. Table XVII shows the impact on Company A's annual and total

Table XVII

Comparisons Using Rate of Profit as a Competitive Factor

| Case A | Yr 2 | Yr 3 | Yr 4 | Total |
|---|---|---|---|---|
| (I) Rate of Profit | 20.00% | 20.00% | 20.00% | |
| Allocation (Units) | 690,700 | 704,400 | 721,900 | |
| Annual Profit* | $1,267 | $1,174 | $1,083 | $3,524 |
| (II) Rate of Profit | 21.81% | 24.01% | 26.67% | |
| a) Rate of Profit - Not Weighted | | | | |
| Allocation (Units) | 669,000 | 674,400 | 680,200 | |
| Annual Profit* | $1,338 | $1,349 | $1,360 | $4,047 |
| b) Rate of Profit weighted at (-0.65) | | | | |
| Allocation (Units) | 605,200 | 581,400 | 553,000 | |
| Annual Profit* | $1,210 | $1,163 | $1,106 | $3,479 |
| c) Rate of Profit weighted at (-0.75) | | | | |
| Allocation (Units) | 591,000 | 561,800 | 526,800 | |
| Annual Profit* | $1,182 | $1,124 | $1,054 | $3,359** |

* Annual Profit is given in $1,000's.
** Difference is due to rounding of figures to nearest $1,000.

profits for test Case A when the rate of profit is included as an additional competitive factor with weights of (-0.65) and (-0.75). It is assumed that for Years 2 through 4 the rate of profit for Company B equals $\underline{s}_x$, the established standard rate of profit for the competition, at 20.00% of cost.

Comparison of the results listed in Table XVII reveals the following. For Case A (I), with a constant 20.00% rate of profit and no gaming, Company A earns a total profit of $3,523,842. But when Company A converts cost decreases to

profit increases, the total profits range from $4,047,200, when not included as an additional competitive factor, down to $3,359,200, when rate of profit is weighted at (-0.75). The weight of (-0.75) decreases the gamed profits by more than $160,000 from what the profits are without gaming, whereas the weight of (-0.65) decreases them less than $45,000. Therefore, the greater the negative weight assigned to the rate of profit, the greater the degree of deterence provided by the proposed allocation technique. And, along with the direct deterence resulting from decreased profits, the competitive position of Company A could be weakened due to the larger allocations which would be awarded to the competing contractor, Company B.

There is a limit on the deterence provided by including the rate of profit as an additional competitive factor. When the competitor having the higher overall competitive index would be awarded only the MAR allocation, even without gaming, the possible increase of that index would provide no deterence. The MAR allocation would be received in either case. This use of the MAR restriction to protect high profits is the last gaming strategy to be discussed in this section.

Use of the MAR to Protect High Prices. The MAR allocation is intended to prevent the high index competitor from being forced out of the competition during the following years. Included in the awarding of an MAR allocation

is the implicit assumption that the high index competitor will attempt to improve his posotion through superior competitive performance in the following years. However, because the MAR guarantees a predetermined minimum allocation, the high index competitor may elect a strategy which substitutes use of the MAR for competitive performance as the means to acquire greater profits.

Simply stated, in this last gaming strategy the high index competitor resigns himself to accepting the MAR allocation and then submits unit line price bids based on whatever rate of profit he selects. Regardless of the ratio of the overall competitive indices, the high index competitor knows that he will be awarded at least the MAR allocation. This makes it possible for the high index competitor to convert any, or all, cost reductions to profit increases without fear of receiving reduced allocations. As a matter of fact, he could even increase unit profit by an amount greater than any unit cost reduction and still not have a reduction in the allocation received.

The most significant difference between this strategy and the previous one is that, in the previous strategy, the allocations awarded to the gaming competitor declined each year, whereas in this strategy, the allocations remain constant at the MAR allocation level. Inclusion of the rate of profit as an additional competitive factor would have no effect on a competitor who already is at the MAR level.

The proposed allocation technique has no means with which to deter this type of gaming. However, it is not this lack of a deterent which should concern the procuring agency. Rather, the procuring agency should be concerned about the fact that it is using a procurement method (the proposed allocation technique) which is intended to give a contractor, who would otherwise be unable to compete, an opportunity to compete, regardless of any initial advantage his competitor might have, and that contractor refuses to make a legitimate attempt to compete. Under these conditions, the procuring agency would have no alternative but to change to another method of determining the allocations.

## V. CONCLUSIONS AND RECOMMENDATIONS

### Introduction

The allocation technique presented in this thesis is intended for use in a very uncommon procurement scenario. However, individual parts, or features, of the proposed allocation technique may prove to be beneficial if applied to other types of competitive procurements. The three main features which will be discussed in this chapter are: the use of competitive indices, rather than unit line price bids, as a measure of competitive performance; the use of ratios to compare the performance of the competitors; and, the procedure used to determine the allocations to be awarded each competitor based on the ratio of the competitive indices.

### Competitive Indices

The use of indices to measure the competitive performance of contractors is discussed in Chapter II of this thesis. The calculation of these indices is demonstrated in Chapter IV.

Conclusions. The use of a competitive index allows for the inclusion of any additional factors which the procuring agency deems appropriate to the competition. It is through the inclusion of additional factors that the particular product being offered for procurement becomes as significant

as the price of the product in selecting a source of supply. In a typical procurement, the selection of a vendor is determined solely of the basis of the lowest price bid for an item which either meets or exceeds certain minimum criteria or specifications. But, no allowance is made for the different degrees to which various items either meet or exceed these minimum requirements. For example, assume the procurement item is some type of vehicle. The specifications for this vehicle are that it be able to transport a load of at least 2,000 pounds and that it must travel more than 15 miles on a gallon of fuel. Now, if two vendors were to bid on this procurement, one offering a vehicle which is rated at 2,000 pounds and 20 miles per gallon, and the other offering a vehicle which is rated at 4,000 pounds and 30 miles per gallon, the selection of a contractor becomes indifferent as to product performance and is made solely on the basis of the unit line price bids.

Awarding of a contract solely on the basis of lowest bid price may, in some cases be appropriate. However, such cases would require that there be little or no difference in the benefits derived from the products of the competing contractors. To award contracts on a price-only basis is to ignore the fact that there are different kinds of cost-benefit comparisons - any one of which may apply to the alternatives of any given procurement. "Basically, there are three relationships that the cost and benefits of vari-

ous alternatives may have. These relationships are:

(a) Equal benefits - unequal cost.

(b) Equal cost - unequal benefits.

(c) Unequal cost - unequal benefits"(Ref 1 :3-5).

The price-only awarding of contracts artificially forces all comparisons to be made on the basis of equal benefits and unequal cost. This is due to the fact that all products are judged only as to whether or not they either meet or exceed certain minimum requirements/specifications. Those which do not are eliminated from the procurement competition. But, for those products which satisfy all the requirements, no additional benefits are assigned to reflect the degree to which the minimum requirements may have been exceeded. All are considered as if they were of equal benefit.

Using the vehicle procurement example from the earlier part of this section, assume the first vehicle (2,000 pound load and 20 miles per gallon) has a bid price of $10,000, and the second vehicle (4,000 pound load and 30 miles per gallon) a bid price of $10,500. Normal procurement practices would result in the selection of the first vehicle because it has a bid price which is $500 less. But, does it really cost less? With gas prices at one dollar per gallon (which many people believe will be the case by mid 1979), the fuel cost savings for the second vehicle will make up the $500 difference in the first 30,000 miles of operation. Furthermore, this does not include any savings due to the reduced number of loads which might be required because of

the greater load carrying capability of the second vehicle. Such a reduction in the number of loads may, in turn, allow for reductions in the number of vehicles required, as well as the number of vehicle operators, maintenance personnel and maintenance facilities.

The most difficult part of using an index to measure competitive performance would not be, in the opinion of this writer, the selection of the factors to be used in determining the index. But rather, the greatest difficulty would be the assignment of a weight to each of the factors selected. As discussed in Chapter II, the weight which is to be assigned to any given factor is based on the value of a one percent change in that factor compared to a one percent change is the unit bid price of the procurement item.

The means used to determine the value of a particular factor may range anywhere from a subjective decision, if the benefits are intangible, to a highly analytical decision requiring complex modeling techniques, if the factor has measurable impacts in several areas. The selection of the specific means used to determine the value of any factor is left to the discretion of the procuring agency. However, the amount of effort which goes into determining this value must be commensurate with the value of the benefits to be derived by its inclusion.

Recommendations. Consideration should be given to the use of an index as the measure of competitive performance in other types of competitive procurements. The additional factors used to determine the index are similar to what is found in a multiple incentive type contract. The use of an index with additional factors, and the use of incentive contracts, are both "designed to encourage contractors to improve their contract performance in the area of cost and sometimes in quality performance and...may also be extended to encompass equipment performance, including reliability, and schedule incentives"(Ref 2:35). Additionally, both are based on harnessing the profit motive to reduce costs and improve the product. (Ref 2:35) The most significant difference between the two is that the competitive index is used to determine which competitor will be awarded the contract, whereas the incentive contract is used to determine the profit for a contract on which performance has already taken place. Because of this timing difference, two added benefits are possible with the use of competitive indices. First, the competitive index method harnesses the profit motive of all the competitors, rather than just that of the competitor who is awarded the contract. And second, the use of competitive indices enables the procuring agency to negotiate fixed price contracts, rather than contracts in which the total price is not known until after completion.

The use of competitive indices is also recommended on

the grounds that the weights assigned to the various additional factors would provide signals to industry as to what areas are of the greatest importance to the Government. A trend of either increasing or decreasing weights being assigned to particular factors would indicate where emphasis should be concentrated. Had fuel consumption been included as a competitive factor over the past several years, the trend, especially in more recent years, would undoubtedly have been for the weight assigned to this factor to have increased. As a result, the efforts of industry to develop more energy efficient products might have commenced sooner, and with a great deal more fervor.

For the future, if the desires of the President for "voluntary" price controls are to be met, price increases could be included as additional factors and weighted so as to encourage adherence to whatever guidelines are established. Companies with price increases which exceed the guidelines would not necessarily be barred from Government contracts. They would, though, find it much more difficult to compete. Under this course of action the Government would not be forced, by its own policies, to forego what may be a superior product solely because a competitor increased prices more than a predetermined amount. The result would be that a contractor who exceeded the guidelines for price increases would be penalized, but the Government would still be able to select the best alterna-

tive, all things considered.

## Ratios

The use of ratios to compare the performance of the various competitors is discussed in Chapter II of this report.

Conclusions. The use of ratios to compare competitive performances is restricted to procurement scenarios in which two or more competitors are to be awarded contracts for the same, or similar, products. The purpose for which these ratios are used is to determine the portions of the total procurement quantity which are to be allocated to each of the competitors. However, in order to determine a ratio, a single number must be selected to represent the performance of each of the competitors. The means by which to select this number, as presented in the proposed allocation technique, is to determine an overall index for each of the competitors. This index may be determined in such a way as to include competitive factors along with the bid price, or it may be the average bid price by itself. (This use of an index is discussed in the previous section of this chapter.)

For the two-contractor procurement scenario, which is the basis of this thesis, the use of ratios rather than absolute differences results in a much more accurate reflection of the relative competitive performances over an extended period of time. This is due to the fact that the

use of absolute differences would not reflect any performance factors which may be due to a disparity in production experience. The main reason behind the use of ratios to compare relative competitive performance is to foster competition between contractors who would otherwise be on different competitive levels. This is the same principle as the use of handicaps in athletic competition. For example, amateur golfers with wide differences in their average abilities compete on an even level by applying handicaps which are based on their past performance. The winner is then determined, not by the lowest absolute score, but rather by the best performance relative to an individual golfer's past experience.

Recommendations. Whenever two or more contractors are needed to satisfy a procurement requirement, consideration should be given to the use of ratios for the determination of the allocation to be awarded each contractor. The establishment of predetermined allocations for the high and low bidders may well discourage the type of active competition which leads to the lowest possible cost in the long run. As discussed in Chapter III of this thesis, it is through the provision for variable allocations to be awarded on the basis of relative competitive performance (as expressed by a ratio of competitive indices) that contractors, who might otherwise resist acting in a competitive manner, can be encouraged to compete to the best of their ability - or at least to a higher degree than what would be expected with

fixed allocations. A more complete discussion of this subject can be found in Chapter III.

The use of ratios to compare competitive performances might be discontinued when, and if, the annual indices of both competitors have become sufficiently close that either competitor could reasonably be expected to be the low bidder. However, increasing the elasticity of the allocation formula may prove to be more beneficial to promoting competition in the long run. (The effect on the allocations of varying the elasticity is demonstrated in Table X of Chapter III.)

The reason that increasing the elasticity may be more beneficial is that, by dropping the use of ratios, the procuring agency is compelled to use fixed allocations. And, depending on the difference in the sizes of these allocations, the result could be that either competitor, by receiving the smaller allocation, would be left in a noncompetitive position for the following year. What makes the situation even worse, is that the competitor who receives the smaller allocation might have an index (or price) which is anywhere from just slightly higher to a great deal higher. Yet, he is penalized the same in either case. By continuing with the use of ratios and variable allocations, as well as increasing the elasticity, the high bid competitor could still be made to run the risk of becoming noncompetitive. However, the degree of risk, while being controlled by the procuring agency, would vary depending on how much higher the high index is when compared to the low index.

Determination of Contractor Allocations

The procedure used to determine the portion of the annual procurement quantity to be allocated to each of the competitors is discussed in Chapter III. Use of this procedure with the proposed allocation technique is demonstrated in Chapter IV.

Conclusions. The method presented in the proposed allocation technique is very simple, both in the reasoning behind it and in its application. This simplicity is, however, probably the strong point of the method. By keeping it simple, it is easy for the competitors to determine what the magnitude of the effect on their allocations will be, if they vary their unit line price bids. Other methods for determining the allocations based on the ratio of competitive indices could be developed without much difficulty. And the allocations to be awarded using some other method could be made to correspond to those using the proposed method. Even to develop another method in which the MAR allocation can be accounted for by changing just one number would not be very difficult. But, to find another technique in which the elasticity can be changed, over the entire range of possible indices ratios, by changing only one number (r in the proposed method) may prove to be much more difficult.

Figure 5.1 depicts an alternative method which uses a chart to determine the allocations based on the ratio of the

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| RATIO | 1.00 | .90 | .80 | .70 | .60 | .50 | .40 |
| LOW INDEX % | 50.00 | 56.18 | 62.59 | 69.14 | 75.67 | 80.00 | 80.00 |
| HIGH INDEX % | 50.00 | 43.72 | 37.41 | 30.86 | 24.33 | 20.00* | 20.00* |

* MAR Restriction

Figure 5.1. Alternative Allocation Chart

indices. This method, on the surface, appears to be quite simple. But, what happens if the ratio falls somewhere between two of those which are listed? For example, assume the actual ratio is 0.85. What are the allocations now? Does the procuring agency have to plot the allocations versus the ratios and then use a fitted curve to determine the allocations? Or, would straight line interpolation between the .80 and .90 ratio allocations be sufficiently accurate? Once this problem is solved, consideration must be given to the fact that, should the procuring agency decide to change the elasticity of the allocations, an entire new chart must be developed. Oh well, at least the MAR restriction is no problem!

Another alternative method, which uses a line to determine the allocations, can solve some of the problems found with the chart method. See Figure 5.2. The variable allocation line (AA') solves the problem found in the chart method when the actual ratio falls between the ratios which are listed on the chart. Handling any MAR restriction is

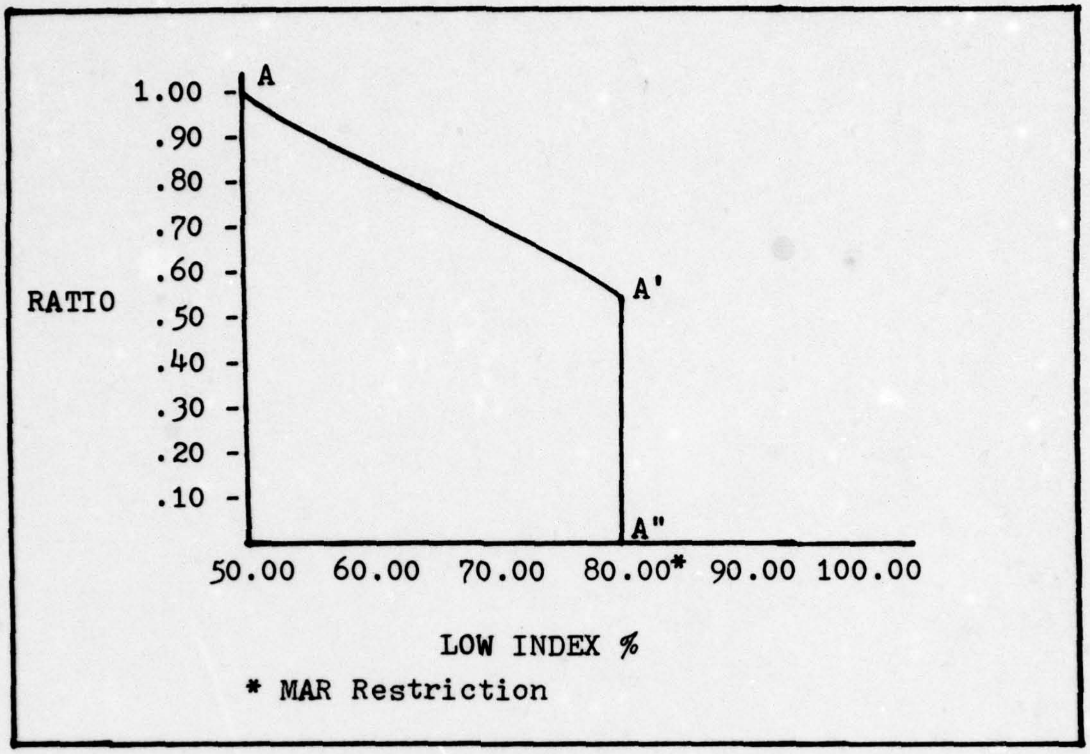



Figure 5.2. Alternative Allocation Line Method

also quite simple with this method - just position the MAR line (A'A") at the maximum allocation level. But again, changing the elasticity requires more than just the change of one number. In this case, line AA' would have to be redefined in order to change the elasticity.

Recommendations. In order to determine the allocations, the method used should be simple enough that everyone who is involved, competitors and procurers, can easily understand it. The method used should also leave no doubt as to what the allocations will be for any given ratio. If a chart is to be used, as in Figure 5.1, either all possible ratios

(allowing for rounding off of numbers) should be listed, or specific procedures must be identified for determining the allocations when the actual ratio falls between those on the chart.

The use of a method similar to the one proposed in this thesis (one in which either the MAR or the elasticity can be altered by changing only one number) easily lends itself to the use of a hand held calculator for rapid and accurate allocation determinations. But, even without the accuracy provided by a calculator, the proposed method does enable the competitors to "eyeball" the results which can be expected from variations in prices or indices. This should add impetus to the desire of the competitors to compete to the best of their abilities.

## Recommendations for Further Studies

Three areas are recommended by this author for further study.

The first area encompasses the selection and weighting of additional factors which might be used in the competition. The method of determining the weights to be assigned may well be much more important than the actual selection of the factors themselves. This is due to the fact that the factors selected merely indicate the preferences of the procuring agency. The weights assigned to these factors, however, must reflect the actual value of these preferences in comparison to the unit line price.

The second area is the determination of the Minimum Award Requirement as discussed in this thesis. Research in this area should include the determination of both the minimum number of units for which it is economically feasible to continue production and the minimum number of units which must be produced for a contractor to remain competitive.

The third area deals more directly with the allocation technique which has been proposed in this thesis effort. The ability of the procuring agency to vary the elasticity of the allocations can be used to encourage more active competition when the annual indices of both competitors have become approximately equal. However, specific research should be conducted to determine whether or not there are any particular criteria by which the procuring agency can determine an optimum elasticity to use for the procurement competition of any given year.

## Bibliography


1. AFR 300-12, Vol. I. Procedures for Managing ADPS. Washington: Department of the Air Force, 12 September 1977.

2. Air Force Institute of Technology. Contract Administration: Vol I. Wright-Patterson Air Force Base, Ohio, 1975.

3. -----. Contract Administration: Vol II. Wright-Patterson Air Force Base, Ohio, 1975.

4. Air Force Systems Command (AFSC). "Program Management Directive R-P200 6 (6) 64605F/GAU-8/A." Wright-Patterson Air Force Base, Ohio, 14 August 1974.

5. Air University. Network Analysis Program Evaluation and Review Technique PERT. Maxwell Air Force Base, Alabama, undated.

6. Alchain, Armen A. and William R. Allen. Exchange and Production Theory in Use. Belmont, California: Wadsworth Publishing Company, Inc., 1969.

7. Chase, Richard B. and Nicholas J. Aquilano. Production and Operations Management. Homewood, Illinois: Richard D. Irwin, Inc., 1977.

8. Horngren, Charles T. Cost Accounting. (Third Edition). Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1972.

9. Mansfield, Edwin. Microeconomics. (Second Edition). New York: W. W. Norton & Company, Inc., 1975.

10. Nadeau, Robert L. Development of GAU-8 Ammunition Production Rate Variance Formula. Unpublished Thesis. Wright-Patterson Air Force Base, Ohio: Air Force Institute of Technology, September,1976.

11. Texas Instruments Inc. Program Manual - Statistics. Dallas: U. S. Calculator Products Division, 1975.

12. Wall, Richard L. Independent Cost Estimate of the GAU-8 Aluminum Cartridge Case. Unpublished Thesis. Wright-Patterson Air Force Base, Ohio: Air Force Institute of Technology, July 1975.

## Vita

Jay L. Pelzer was born on 13 May 1948 in Queens, New York. He attended grade schools in Ohio and California, and two parochial high schools in Southern California. He graduated from the United States Air Force Academy in 1970, with a B.S. in Engineering Management. After completion of undergraduate pilot training at Williams AFB, Arizona, he was assigned to the KC-135 Combat Crew Training School at Castle AFB, California. He was assigned to the 904th Air Refueling Squadron (SAC), Mather AFB, California, in December, 1971. In August of 1976, Captain Pelzer entered the Air Force Institute of Technology as a graduate student in Systems Management.

He is married to the former Jean Louise Marcarelli. They are the proud parents of two sons; James, who was born one month before entering AFIT, and John, who was born one month before leaving.

Permanent Address: 13679 E. Camilla St.
Whittier, California
90601